

CORROSION ABSTRACTS

As Published in

CORROSION Volume 11-1955

Official Publication

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

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PAGE NUMBERS BY MONTHS

Pages (a)

1- 10	January
11- 28	February
29- 48	March
49- 64	April
65-102	May
103-126	June

Pages (a)

127-158	July
159-184	August
185-206	September
207-240	October
241-260	November
261-290	December

INDEX TO CORROSION ABSTRACTS, Volume 11, 1955

Numbers in this table are those printed in the lower outer margins of the Corrosion Abstract Section, cumulative through the volume. Topical headings in the left column are those of the first and second subdivisions of the NACE Abstract Filing Index, revision of September 1952. This index may be found reproduced in full as part of the

Index to Technical Material Published in Corrosion in the December, 1955 issue of Corrosion. Principal difference between this index and that published in the December, 1951 issue is the addition of designation 6.11 Design, Influence on Corrosion. Refer to footnotes for changes in 8, Industries not affecting validity of indexing of previous abstracts.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1 GENERAL													
1. Miscellaneous				49									1
2. Importance		11		49			127	159		207			2
3. Reviews													3
4. Bibliographies					65			159					4
5. Directories of Material	1	11						160					5
6. Books		12		49				160			241		6
7. Organized Studies of Corrosion					65		128	160		207	241		7
8. Personalities and Directories of Individuals													8
2 TESTING													
1. General	1	12					128			208	241		1
2. On Location Tests				49			128				241		2
3. Laboratory Methods and Tests	1	12		50	65		128	160		208	242		3
4. Instrumentation	2		29	51			130	164	185	210	244		4
5. Specifications and Standardization									185				5
6. Preparation and Cleaning of Specimens											244		6
7. Other													7
3 CHARACTERISTIC PHENOMENA													
1. General										210			1
2. Forms	2		30	51	66		134	166		210	244		2
3. Biological Effects								168					3
4. Chemical Effects					66		135	168			245		4
5. Physical and Mechanical Effects	2		34		66		135	168		212	245		5
6. Electrochemical Effects			34		68		136	171		213	245		6
7. Metallurgical Effects	3		36		68		138	172		214	245	261	7
8. Miscellaneous Principles	4						140	174		216		261	8
9. Other													9
4 CORROSIVE ENVIRONMENTS													
1. General													1
2. Atmospheric						103		175		217		262	2
3. Chemicals, Inorganic	4					103	140	176		217			3
4. Chemicals, Organic						104	143	176		217		262	4
5. Soil	4					106		176					5
6. Water and Steam	4		37			106	143	176		217		264	6
7. Molten Metals	5		37				144	177				264	7
8. Other							146						8
5 PREVENTIVE MEASURES													
1. General													1
2. Cathodic Protection		13	38	52		107	146	178		217		264	2
3. Metallic Coatings		14	38		68	108	146	179			246	264	3
4. Non-Metallic Coatings and Paints		14	44	53		110		181	185	218	246	266	4
5. Oil and Grease Coatings									187				5
6. Packaging					72	112							6
7. Treatment of Medium					72	112				218		269	7
8. Inhibitors and Passivators			44	54		112			187	218		270	8
9. Surface Treatment		16	46		72	114	152		190	218		270	9
10. Other					76								10
11. Design, Influence of					76	116							11
12. Metallurgical Treatment						116							12
6 MATERIALS OF CONSTRUCTION													
1. General						116							1
2. Ferrous Metals and Alloys		16		55	77	116	154		194	219		274	2
3. Non-ferrous Metals and Alloys—Heavy	6	18		56	78	116	156	182	198	219		278	3
4. Non-ferrous Metals and Alloys—Light	8	21		56	84	120		182	200	224		282	4
5. Metals—Multiple or Combined Discussion										226		284	5
6. Non-Metallic Materials	9	22		58	84					227	250	284	6
7. Duplex Materials		24		58	86							286	7
8. Other													8
7 EQUIPMENT													
1. Engines, Bearings and Turbines	10	24		59	87	121			203	227	252	286	1
2. Valves, Pipes, and Meters				60	88						252	286	2
3. Pumps, Compressors, Propellers, and Impellers		24		60	88	121				228	252		3
4. Heat Exchangers		24		60	89					228	252	286	4
5. Containers		24			90	122			204	228		288	5
6. Unit Process Equipment		24		60	90	122			204	228			6
7. Electrical Telephone and Radio		24	46	62	92	122			204	229			7
8. Wires and Cables (non-electrical)		25			93					230			8
9. Specifications													9
10. Other					93					230	256		10
8 INDUSTRIES*													
1. Group 1		25			94					230			1
2. Group 2										231	256		2
3. Group 3					94					231			3
4. Group 4		25	46		94					232	256		4
5. Group 5					98			183		234			5
6. Group 6								183					6
7. Group 7			46		98								7
8. Group 8		26			98	124				235	256		8
9. Group 9		26	46		100	124				236	255		9
10. Group 10										238	258		10

* The following designations apply to the several groups listed under 8. INDUSTRIES:

- Air conditioning, architecture and building, refrigeration, sewage and water.
- Communications, power.
- Agriculture, beverage, dairy, fermentation, food, sugar, starch.

- Fuel, solids; fuel, gases; petroleum refining and production, rubber, atomic energy.
- Ceramics, glass, pulp and paper, wood products.
- Laundry soap and detergents, textiles.
- Graphic arts, instruments, jewelry, photography.

- Chemical manufacturing, distilled liquor, electroplating, leather and tanning, metal fabrication and finishing, pharmaceuticals.
- Aircraft, automotive, pipe line, railroad, shipping.
- Explosives, metallurgy, mining ordnance and war materials, other.

Errata—Volume 11, 1955

Minimizing Stress Corrosion Cracking of Cylinder Valves by M. Schussler. Corrosion, Vol. 11, No. 3, 19-22 (1955) Mar.

Page 20, cutlines, Figure 4, third line should read:

stringers of eutectoid and has a hardness of Rockwell B85. Etchant:

correcting the spelling of "Rockwell."

Page 20, column 2, line 6 should read:

(Rockwell B65) has more alpha and less eutectoid

changing the letter following Rockwell to "B."

Proposed Methods for Cathodic Protection of Composite Structures by M. Unz. Corrosion, 11, 40-43 (1955) Feb. Page 40. Biography. Third and fourth lines to read:

Tel Aviv. He is attending to a cathodic protection scheme of the Mekoroth Water Company

Page 41, column 2. Table 1. For the last line of the table substitute the following:

voltage, $|U|$, expected, volt -0.85 -0.95

correcting the values for voltage.

Severe Pitting of Stainless (18-8) Steel in Hot Chloride Dye-Baths. By Frank N. Speller. Corrosion, Vol. 11, No. 7, 303t (1955) July.

First paragraph, last line, change to read:

years, several metal parts had to be replaced, The welded pipe was made of Type 304 stainless steel.

Third paragraph, change first sentence to read:

The localized attack at fusion welds was associated with stress-corrosion cracks and carbide precipitation, which led to the disintegration of the steel at or near the welds or pores in casings.

Fourth paragraph, fourth line, change to read:

sodium nitrite or sodium chromate to the dye bath

Fourth paragraph, thirteenth line, change to read:

ine ion attack in the final dyeing period. Of course,

Fifth paragraph, second line, change to read:

of inhibitors after removal from the inhibited solution.

The Electrochemistry of Inhibitor Action. By R. B. Mears. Corrosion, Vol. 11, No. 8, 362t-364t (1955) Aug.

Substitute the illustration below for Figure 1 on Page 363t.

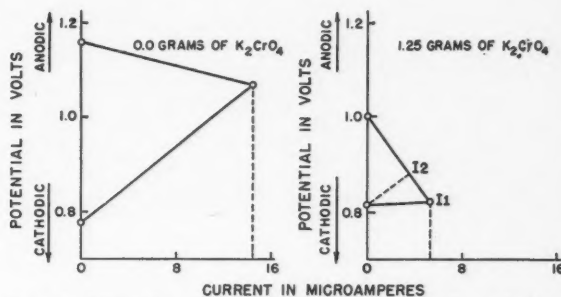


Figure 1—Effect of concentration of chromate on local cells on aluminum in 10 percent sodium chloride solution.

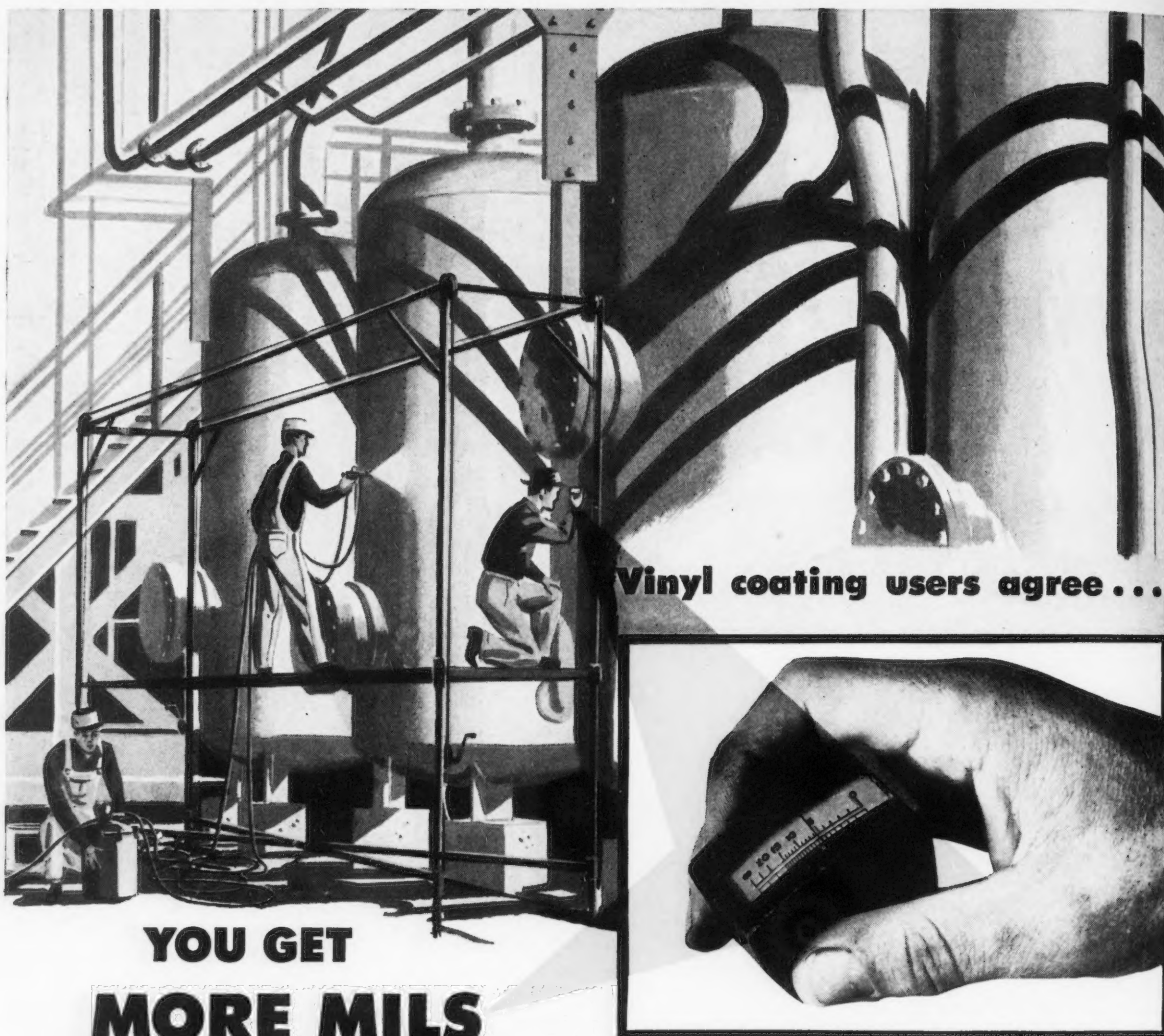


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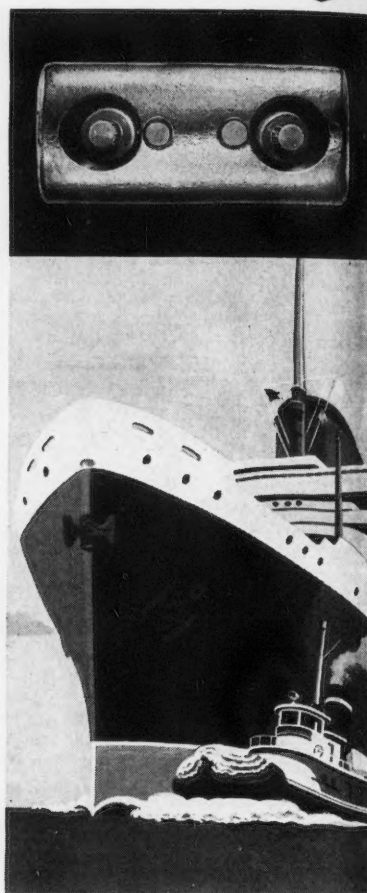
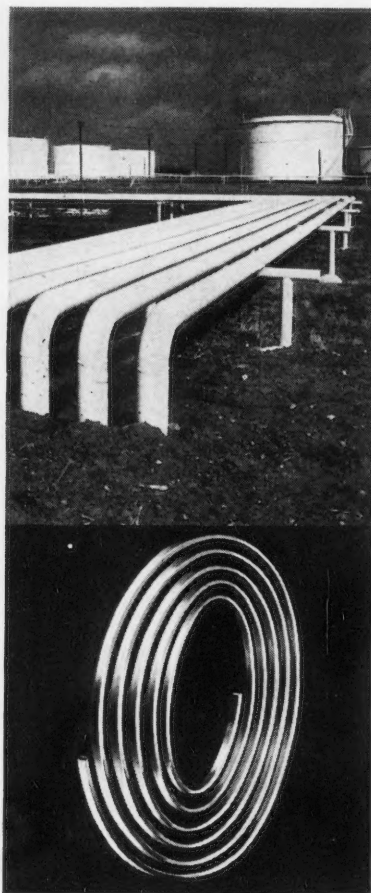
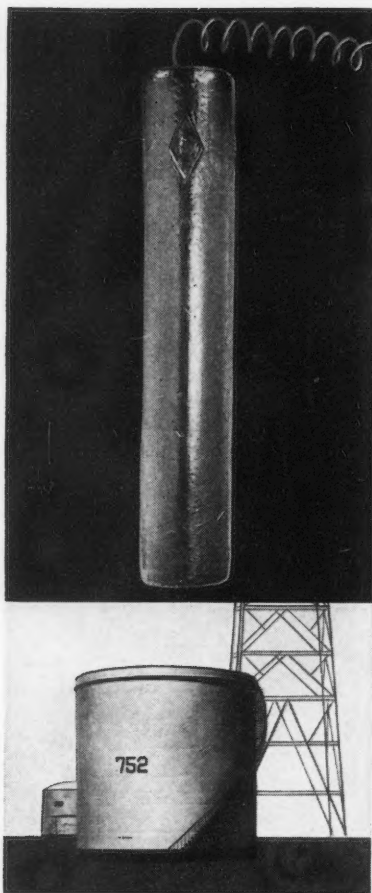
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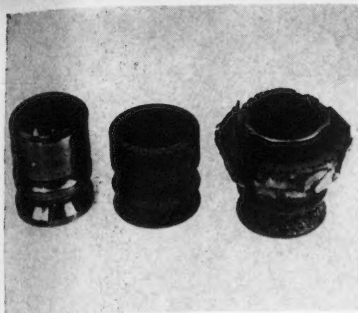
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THIS MONTH'S COVER—Catastrophic effect of 1/4-gram of contaminant (V_2O_5 , 74.4%; Na_2SO_4 , 10.2%; SiO_2 , 5% and about 2% each of PbO , FeO , NiO , Cr_2O_3 and Al_2O_3) in synthetic fuel oil ash on a heat resistant alloy is shown. Left specimen is before test; center after exposure to air at 1550 F for 100 hours and right, same exposure with contaminant added. Specimens tested under a Bureau of Ships program at University of Tennessee. (See Topic of Month, this issue.)



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Vol. 11

January, 1955

No. 1

CONTENTS

Directory of NACE Technical Committees.....	Page 4
Officers and Directors, National Association of Corrosion Engineers.....	Page 16

TECHNICAL SECTION

Topic of the Month—Catastrophic Corrosion Resulting from Vanadium Pentoxide in Fuel Oil Ash	Page 17	Important Advantages of Titanium in the Chemical Industry	Page 57
By Anton deS. Brasunas		By W. G. Renshaw and Perry R. Bish	
Laboratory Evaluation of Inhibitors for Sweet Gas-Condensate Wells	19	Discussion: William W. Wheeler, Page 62; F. L. Whitney, Jr., Lyle A. Timm, Garland M. Riegel, E. Richard Sprague; Replies by W. G. Renshaw and Perry R. Bish, Page 63.	
By P. J. Rafsnider, R. S. Treseder and A. Wachter		Use of Organic Inhibitors in Refinery Distillation Process Equipment	64
Effect of Minor Constituents on the Intergranular Corrosion of Austenitic Stainless Steels	22	By G. E. Purdy	
By J. J. Heger and J. L. Hamilton		DISCUSSIONS	
Effect of Design, Fabrication and Installation on the Performance of Stainless Steel Equipment	27	Underground Corrosion Round Table, Kansas City, 1954: James Robert Cowles, David Hendrickson, Sidney K. Gally, Orville W. Zastrow, Kenneth Dudley, Wahlquist, Fred R. Blankenship, Jr., Charles L. Mercer, Marshall E. Parker, Harold C. Boone, Page 68; Clifford S. Jones, Page 69.	
By James A. Collins		Cathodic Protection of Florida Power and Light Company's Generating Plants by Joseph B. Prime. Discussions by Harrison G. Burbidge, Robert C. Mill, Rodney B. Teel; Replies by J. B. Prime, Page 69.	
Corrosion Aspects of the Vanadium Problem in Gas Turbines	35	Industrial Applications of a Method for Measuring Small Amounts of Corrosion Without Removal of Corrosion Products by Andrew Dravnieks and Horace A. Cataldi. Discussion by Frank L. LaQue; Reply by Andrew Dravnieks, Page 69.	
By S. H. Frederick and T. F. Eden		Aluminum Alloy Heat Exchangers in the Process Industries by W. W. Binger and H. W. Fritts. Discussions by Bryant West Bradley, Page 69; Gerard Sorrel, F. L. Whitney, Jr., Hugh P. Godard, Frank C. Bunker, Andrew Dravnieks, Harold Smith, Page 70; Replies by W. W. Binger and Harry W. Fritts, Pages 70, 71.	
Discussion: A. Lewis, Page 45; H. Lewis, J. J. Macfarlane, N. Stephenson, Page 46; R. L. Samuel, T. P. Hoar, Page 47; C. Sykes, H. T. Shirley, Page 48; Reply by S. H. Frederick and T. F. Eden, Page 49.			
Notes on a System for Rating Pitting Corrosion	50		
By Russell W. Henke			
Cathodic Protection of Open Box Coolers	53		
By J. P. H. Zutphen			

NACE REGIONAL AND SECTIONAL NEWS

Page	Page
185 Attend Western Region Conference..... 73	Kansas City Hears Wren on Holiday Detectors..... 76
UCLA Holds Protective Coatings Short Course..... 73	Whitney Talks on Materials Selection..... 76
Edmonton Section's Rules Approved..... 73	Short Course Calendar..... 76
Western Region 1955 Conference Set..... 73	Pittsburgh Section..... 76
Detroit Section to Sponsor Corrosion Panel..... 74	NACE Calendar..... 78
22 Attend Corpus Christi Meeting..... 74	U. Tennessee Course to Feature Fundamentals..... 78
Boiler Corrosion Panel Held..... 74	57 Firms Take Exhibit Space..... 79
Oklahoma U. Short Course..... 74	Ell's to Talk at Houston..... 79
Fretting Corrosion Is Ohio Valley Topic..... 75	Four Southwestern Ohio Section Meetings Set..... 79
Refractories Discussed at Beaumont..... 75	Schenectady-Albany-Troy Hears Maitland..... 79
Talk by Friend Scheduled at Philadelphia..... 75	Program for Houston Section Short Course..... 80
Sudrablin Talks at Chicago..... 76	UCLA Short Course Set..... 80
Greater Boston Section Hears de Bethune..... 76	Book Reviews..... 80
Process Equipment Discussed at Cleveland..... 76	F. J. Radd Addresses North Texas Section..... 81
Fluorocarbon Symposium..... 76	Whitney to Talk at Detroit..... 81
	San Francisco Bay Section Hears Dancy..... 81

TECHNICAL COMMITTEE NEWS

Page	Page
Record Number of Meetings Planned for Chicago..... 83	Report on Epoxy Coatings on T-6A Agenda..... 90
Water Meter Corrosion Task Group Formed..... 83	Committees Reach High Activity Level in 1954..... 90
27 T-1 Members, Guests Meet on W. Kansas Section..... 83	High Purity Water Corrosion Resistant Materials Discussed..... 91
Tentative Schedule of Technical Committee Meetings at Chicago..... 84	Identification of Corrosion Products Is Topic..... 93

GENERAL NEWS OF CORROSION INTEREST

Page	Page
Changes Made in Corrosion's Numbering System..... 94	ASME Corrosion Papers..... 95
Smith Named to NACE Board..... 94	Petroleum Industry Nondestructive Testing Methods Reviewed..... 96
Air Pollution Course Scheduled at NYU..... 94	By F. A. Prange..... 96
Papers at Italian Corrosion Meeting Listed..... 95	Technical Aids Offered for Small Businesses..... 98
	New Products..... 100

Index to Corrosion Abstracts.....	103
Index to Advertisers.....	112

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• T-2A-1 Galvanic Anode Operating Installations

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T-2B Anodes For Impressed Currents

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T-2C Minimum Current Requirements

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• T-2C-1 Criteria for Cathodic Protection

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T-2D Standardization of Procedures For Measuring Pipe Coating Leakage Conductance

W. E. Huddleston, Chairman, Huddleston Engineering Co., Box 998, Bartlesville, Okla.

L. F. Heverly, Vice Chairman, Buckeye Pipe Line Co., 137 W. North Street, Lima, Ohio

T-2E Internal Corrosion of Product Pipe Lines and Tanks

Ivy M. Parker, Chairman, Plantation Pipe Line Co., Box 1743, Atlanta, Georgia

Raymond Hadley, Vice Chairman, Sun Pipe Line Co., 1608 Walnut, Philadelphia 3, Pa.

T-2F Internal Corrosion of Crude Oil Pipe Lines and Tanks

John C. Watts, Jr., Chairman, Humble Pipe Line Co., Box 1390, Midland, Texas

R. L. Elkins, Vice Chairman, Shell Oil Co., Box 1509, Midland, Texas

T-2G Coal Tar Coatings for Underground Use

T. F. P. Kelly, Chairman, Mayvor-Kelly Co., 660 M & M Building, Houston 2, Texas

W. F. Fair, Jr., Vice Chairman, Koppers Co., Inc., Tar Products Div., Box 390, Westfield, New Jersey

T-2H Asphalt Type Pipe Coatings

R. J. Schmidt, Chairman, California Research Corp., 576 Standard Avenue, Richmond, Cal.

P. E. Reynolds, Vice Chairman, Pacific Gas & Electric Co., 245 Market St., San Francisco, California

T-2J Pipe Wrapping Materials

Clark A. Bailey, Chairman, Johns-Manville Sales Corp., 22 East 40th St., New York 16, N. Y.

T-3 GENERAL

F. M. Watkins, Chairman, Sinclair Research Laboratories, Inc., 400 East Sibley Blvd., Harvey, Ill.

F. W. Fink, Vice Chairman, Battelle Memorial Institute, 505 King Avenue, Columbus, Ohio

T-3A Corrosion Inhibitors

Robert S. Wise, Chairman, National Aluminate Corp., 6216 West 66th Place, Chicago, Ill.

J. L. Wasco, Vice Chairman, The Dow Chemical Co., Bldg. 438, Midland, Michigan

T-3B Identification of Corrosion Products

A. H. Roebuck, Chairman, Production Research Division, Continental Oil Company, Ponca City, Okla.

D. A. Vaughan, Vice Chairman, Battelle Memorial Institute, 505 King Avenue, Columbus, Ohio

T-3C Annual Losses Due to Corrosion

F. N. Alquist, Chairman, The Dow Chemical Co., Bldg 438, Midland, Michigan

T-3D Instruments For Measuring Corrosion

H. N. Hayward, Chairman, Engineering Experiment Station, University of Illinois, Urbana, Illinois

F. W. Ringer, Vice Chairman, 7 Hampden Ave., Narberth, Pa.

• T-3D-1 Electrical Holiday Inspection of Coatings

Lyle R. Sheppard, Chairman, 6522 Mercer St., Houston, Texas

T-3E Railroads

R. A. Bardwell, Chairman, Chicago & Eastern Illinois Railroad, Danville, Illinois

G. M. Magee, Vice Chairman, Assoc. Amer. Railroads, Technology Center, Chicago 16, Illinois

• T-3E-1 Corrosion of Railroad Tank Cars

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C. M. Jekot, Vice Chairman, Lithco Corporation, 333 West 40th Place, Chicago 9, Ill.

L. R. Honnaker, Vice Chairman, Engineering Materials Group, Engineering Dept., E. I. DuPont de Nemours & Co., Inc., Wilmington, Delaware

• T-3E-2 Corrosion in Railroad Hopper Cars

Robert Byrne, Chairman, Assoc. Amer. Railroads, 3140 South Federal Street, Chicago 16, Illinois

Directory of NACE Technical Committees

T-3F Corrosion by High Purity Water

D. J. Depaul, Chairman, Westinghouse Electric Corp., Box 1526, Pittsburgh 30, Pa.

J. F. Eckel, Vice Chairman, General Electric Co., KAPL, Schenectady, New York

T-3G Cathodic Protection

T. P. May, Chairman, The International Nickel Co., Inc., 67 Wall St., New York, N. Y.

T-3H Tanker Corrosion

W. S. Quinby, Temporary Chairman, The Texas Co., 135 East 42nd St., New York, N. Y.

T-4 UTILITIES

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Irwin C. Dietze, Vice Chairman, Dept. of Water & Power, Box 3669, Terminal Annex, Los Angeles, Calif.

T-4A Effects of Electrical Grounding on Corrosion

Ray M. Walnwright, Chairman, University of Illinois, Department of Electrical Engineering, Urbana.

T-4B Corrosion of Cable Sheaths

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D. T. Rosselle, Vice Chairman, Southern Bell Tel. & Tel. Co., 1432 Hurt Bldg., Atlanta, Ga.

T-4B-1 Lead and Other Metallic Sheaths

T. J. Mattland, Chairman, American Tel. & Tel. Co., 32 Sixth Ave., New York 13, New York

T-4B-2 Cathodic Protection

R. M. Lawall, Chairman, Amer. Tel. & Tel. Co., 1538 Union Commerce Bldg., Cleveland 14, Ohio

J. J. Pokorny, Vice Chairman, Cleveland Elec. Illuminating Co., 75 Public Sq., Cleveland 1, Ohio

T-4B-3 Tests and Surveys

J. C. Howell, Chairman, Public Service Electric & Gas Co., 200 Boyden Ave., Maplewood, New Jersey

D. R. Werner, Vice Chairman, American Tel. & Tel. Co., 324 East 11th St., Kansas City, Missouri

T-4B-4 Protection of Pipe Type Cables

H. W. Dieck, Chairman, Long Island Lighting Co., 250 Old Country Road, Mineola, Long Island, N. Y.

T-4B-5 Non-Metallic Sheaths and Coatings

G. H. Hunt, Chairman, Simplex Wire & Cable Co., 79 Sidney St., Cambridge 39, Massachusetts

T-4B-6 Stray Current Electrolysis

J. Svetlik, Chairman, Northern Indiana Public Service Co., 5265 Hohman Ave., Hammond, Indiana

G. H. Cantwell, Vice Chairman, Indiana Bell Telephone Co., 240 N. Meridian St., Indianapolis, Indiana

T-4D Corrosion By Deicing Salts

M. B. Hart, Chairman, Illinois Bell Telephone Co., 208 West Washington St., Chicago 6, Illinois

J. A. Temmerman, Vice Chairman, City of Rochester, 242 Main Street W., Rochester, New York

T-4E Analysis of Domestic Waters

V. V. Kendall, Chairman, National Tube Division, United States Steel Corp., P. O. Box 266, Pittsburgh 30, Pa.

T-4F Materials Selection for Corrosion Mitigation in the Utility Industry

David Hendrickson, Chairman, East Bay Municipal Utility District, 512 Sixteenth Street, Oakland 23, Cal.

Robert R. Ashline, Vice Chairman, Department of Water & Power, Box 3669, Terminal Annex, Los Angeles 54, Cal.

T-5 Corrosion Problems in the Process Industries

Paul J. Gegner, Chairman, Columbia-Southern Chemical Corp., Barberton, Ohio

William G. Ashbaugh, Vice Chairman, Carbide & Carbon Chemical Co., Texas City, Texas

T-5A Chemical Manufacturing Industry

R. I. Zimmerman, Chairman, Westvaco Chlor-Alkali Div., Food Machinery & Chemical Corp., Drawer 8127, Charleston 3, West Virginia

T-5A-1 Sulfuric Acid

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W. A. Luce, Vice Chairman, The Duriron Co., Box 1019, Dayton, Ohio

T-5A-2 Stress Corrosion Cracking in Alkaline Solutions

C. F. Pogacar, Chairman, Atlantic Refining Co., 260 South Broad St., Philadelphia, Pennsylvania

T-5A-3 Acetic Acid

H. O. Teeple, Chairman, The International Nickel Co., Inc., 67 Wall St., New York, New York

T-5A-4 Chlorine

R. I. Zimmerman, Chairman, Westvaco Chemical Division, Food Machinery & Chemical Corp., Drawer 8127, Charleston 3, West Virginia

T-5A-5 Nitric Acid

J. L. English, Chairman, Oak Ridge National Laboratory, Box P, Oak Ridge, Tenn.

J. L. McPherson, Vice Chairman, No. 3 Murdock Ave., R. F. D. 2, Library, Pa.

T-5B High Temperature Corrosion

John Halbig, Chairman, Armco Steel Corp., Middletown, Ohio

T-5B-1 Exposure Tests

E. N. Skinner, Chairman, The International Nickel Co., Inc., 67 Wall St., New York, New York

T-5C Corrosion by Cooling Waters

T-5C-1 Corrosion by Cooling Waters (South Central Region)

J. L. Ragan, Chairman, Celanese Corp., Box 148, Bishop, Texas

E. L. Halle, Vice Chairman, Monsanto Chemical Co., Box 1311, Texas City, Texas

R. H. Maurer, Secretary, Celanese Corp., Box 148, Bishop, Texas

T-5D Plastic Materials of Construction

Raymond B. Seymour, Chairman, Atlas Mineral Products Co., Mertztown, Pennsylvania

B. J. Phillibert, Vice Chairman, Mathieson Chemical Corp., 820 N. Franklinton Rd., Baltimore, Maryland

S. W. McIlrath, Secretary, 151 E. 214 St., Euclid 23, Ohio

T-5D-1 Questionnaires

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B. J. Phillibert, Vice Chairman, Mathieson Chemical Corp., Baltimore 3, Maryland

S. W. McIlrath, Secretary, 151 E. 214 Street, Euclid 23, Ohio

T-5D-2 Inorganic Acids

Edward Layman, Chairman, Diamond Alkali Company, P. O. Box 686, Pasadena, Texas

R. L. Hughes, Vice Chairman, Spencer Chemical Co., 1231 Woodswether Rd., Kansas City, Missouri

J. F. Malone, Secretary, B. F. Goodrich Chemical Co., 2060 East Ninth Street, Cleveland 15, Ohio

T-5D-3 Inorganic Alkalies

Peter Kimen, Chairman, Champion Paper & Fibre Co., Box 872, Pasadena, Texas

K. T. Snyder, Vice Chairman, Atlas Mineral Products Co. of Pennsylvania, Inc., Box 15227, Houston, Texas

L. B. Connelly, Secretary, Eastman Chemical Products Co., 1001 State National Building, Houston 2, Texas

T-5D-4 Gases

Beaumont Thomas, Chairman, Stebbins Eng. & Mfg. Co., Eastern Blvd., Watertown, New York

J. L. Forse, Vice Chairman, Dow Chemical Company, Plastics Technical Service, Midland, Michigan

William Eakins, Secretary, Chemical Corporation, Plant-tank Division, West Warren, Massachusetts

T-5D-5 Water and Salt Solutions

J. S. McBride, Chairman, Owens-Corning Fiberglass, 16 E. 56th Street, New York, New York

Paul Elliott, Vice Chairman, Naugatuck Chemical Company, Kralastic Development, Naugatuck, Connecticut

T-5D-6 Organic Chemicals

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B. H. Pusey, Vice Chairman, Bakelite Co., Div. of U.C.C., Bound Brook, New Jersey

Wade Wolfe, Jr., Secretary, 73 Ermann Drive, Buffalo 17, New York

T-5D-7 Engineering Design

O. H. Fenner, Chairman, Monsanto Chemical Company, 1700 South Second Street, St. Louis 4, Missouri

K. A. Phillips, Vice Chairman, American Zinc, Lead & Smelting Co., P. O. Box 495, East St. Louis, Illinois

W. B. Meyer, Secretary, St. Louis Metallizing Co., 625 South Sarah, St. Louis 10, Missouri

T-5D-8 Methods and Criteria for Evaluating Plastics in Chemical Environment

R. F. Clarkson, Chairman, Mathieson Chemical Corp., P. O. Box 552, Pasadena, Texas

R. Lembeck, Secretary, Cities Service Res. & Dev. Co., 920 East Third, Tulsa 3, Oklahoma

(Continued on Page 6)

Directory of NACE Technical Committees

T-6 Protective Coatings

A. J. Liebman, Chairman, Pittmar Centrifugal Machine Corp., 1319 Varner Drive, Pittsburgh 27, Pennsylvania

L. L. Whiteneck, Vice Chairman, Long Beach Harbor Dept., 1333 El Embarcadero, Long Beach 2, California

T-6A Organic Coatings And Linings For Resistance To Chemical Corrosion

R. McFarland, Jr., Chairman, Hills-McCanna Co., 3025 N. W. Ave., Chicago 18, Illinois

C. G. Munger, Vice Chairman, Amercoat Corp., 4809 Firestone Blvd., South Gate, Calif.

J. J. Ondrejcin, Secretary, E. I. du Pont de Nemours & Co., Inc., Polychemicals Dept., Wilmington, Delaware.

T-6B Protective Coatings for Resistance to Atmospheric Corrosion

L. L. Sline, Chairman; Sline Industrial Painters, 2612 Gulf Terminal Drive, Houston, Texas.

Howard C. Dick, Vice Chairman, Products Research Service, Inc., Box 6116, New Orleans, Louisiana

T-6C Protective Coatings for Resistance to Marine Corrosion

Raymond P. Devoluy, Chairman, The Glidden Co., Room 1310, 52 Vanderbilt Avenue, New York 17, New York.

T-6E Protective Coatings in Petroleum Production

J. L. Robertson, Chairman, Phillips Petroleum Co., Bartlesville, Oklahoma

T-6G Surface Preparation For Organic Coatings

S. E. Jack, Chairman, Aluminium Laboratories, Ltd., Box 84, Kingston, Ontario, Canada

S. C. Frye, Vice Chairman, Research Dept., Bethlehem Steel Co., Bethlehem, Pa.

T-6H Glass Linings And Vitreous Enamels

G. H. McIntyre, Chairman, Ferro-Enamel Corp., Harvard & 56th Street, Cleveland 5, Ohio

T-6K Corrosion Resistant Construction With Masonry And Allied Materials

L. R. Honnaker, Chairman; E. I. du Pont de Nemours & Co., Inc., Engineering Department, Louviers Building, Newark, Del.

George P. Gabriel, Vice-Chairman; Atlas Mineral Products Company, Mertztown, Pa.

T-6M Field Coating Inspection

L. L. Whiteneck, Chairman, Long Beach Harbor Dept., 1333 El Embarcadero, Long Beach 2, California.

T-6R Protective Coatings Research

Robert H. Steiner, Chairman, Atlas Mineral Products Co., Mertztown, Pennsylvania



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Directories of Region and Section Officers and of Technical Committees

Beginning with this issue of Corrosion the Directories of Regional and Sectional Officers and of Technical Committees will be run on alternate months, beginning with the technical committees in this issue.

On occasion, when the number of changes in the directories makes it advisable, the directories will be run simultaneously.

This change is made in the interest of conserving space in Corrosion and in the belief that bi-monthly publication of these directories will be as useful to NACE members as was the former publication in every issue.



News about COATINGS for METALS

Metallic Organic Decorative Protective

Protective coatings take on tough jobs

Sprayable plastisols offer seam-free thick-film protection

Any metal equipment which can be uniformly heated at 350°F can now be protected with a thick, sprayed-on vinyl plastisol coating. Provided by Unichrome Plastisols, such films resist acids, alkalis, alcohols, water, salt and other corrosive solutions. The heavy build-up, up to 20 mils per coat, assures no weak or thin spots to give corrosion a toe hold. The spraying assures a seam-free surface as thick or as thin as economy and service conditions dictate.

These features are obtained in Unichrome 5300 Series Coatings. They often permit ordinary metals to be used instead of costly alloys.

Phenolic coatings applied by specialists

Phenolic coatings give a good account of themselves in the battle against corrosion. Where facilities exist for baking large equipment, Ucilon Coating 1501 stands ready to deliver a hard finish resistant to acids, solvents, oils, water and other paint-damaging agents.

Lack of such facilities need be no barrier to utilizing phenolics. Many strategically located companies specializing in coating application now exist. Equipment shipped to these specialists will be returned with the tough, long-life protection provided by Ucilon 1501. Ask us for the names of these specialists—or for more information on Ucilon 1501.

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Ucilon Coating System, lining tanks used in beverage processing, prevents contamination and protects flavor

Applications once thought impractical now virtually routine with Systems of Ucilon® Protective Coatings

Uses for chemical-resisting protective coatings keep widening. Where good results were once unobtainable, Ucilon Coating Systems now deliver outstanding protection against corrosion plus unusually long service life in constant contact with strong chemical solutions.

MAKING TANKS IMPERVIOUS

50,000-gallon, concrete, fuel storage tanks are now lined with a Ucilon Coating System applied over special latex, protecting against attack by the aviation. gas and guarding against fuel contamination.

The answer to many brine corrosion problems has been found in a new Ucilon System that provides thicker than ordinary vinyl coatings. Applied to brine clarifier tanks by a leading chemical producer, this system is in perfect condition after 14 months service. Before, nothing ever

lasted more than 60 to 90 days.

Another Ucilon Coating System has solved a tough problem in protecting interiors of tank cars carrying saturated ammonium nitrate solution. One user reports no failure even after two years service. Ucilon protection saves shippers of these fertilizers the high cost of special alloy tank cars.

THE KEY TO SUCH RESULTS

Specialized corrosion control has made the difference. Sixteen systems of Ucilon Protective Coatings provide the variety of specialized materials and coating combinations needed to beat hundreds of corrosives. They offer the properties required for contact with strong solutions and fumes. They block corrosion, save maintenance, equipment and money.

See more details by sending for Bulletin MC-8.

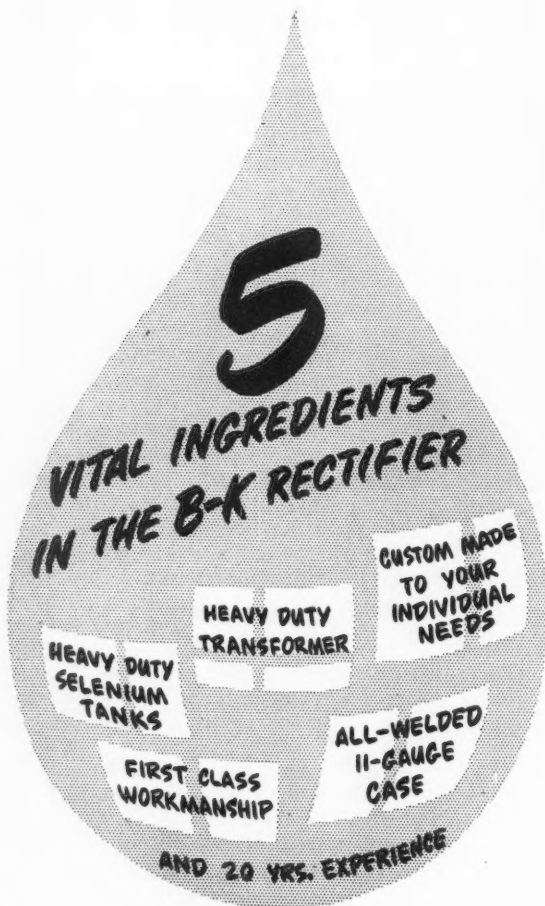
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Chlorine Bromine Fluorine

... or their compounds

When you have a corrosion or purity problem connected with the handling of halogens or halides, consider the use of the Inco Nickel Alloys. They are among the few metallic materials which are successfully used to resist corrosion by chlorine, bromine, fluorine and their halides.

Chlorine—Tests as well as practical experience have shown nickel and the high-nickel alloys to be among the most useful of the common engineering materials for handling dry chlorine at temperatures up to 1000°F.

Bromine—The high resistance of Monel shipping drums to dry bromine has enabled bromine manufacturers to ship this dangerous corrosive in original purity, without fear of contamination or breakage, while cutting shipping costs in some cases by as much as 50%.*

Fluorine—Because nickel and Monel are highly resistant to ignition by fluorine, they are preferred materials for storage cylinders, piping and valves when handling fluorine under pressure.

Sodium Chloride—Potassium Chloride—Manufacturers rely on Inco Nickel Alloys to help preserve product purity during the entire refining operation. High-nickel alloys are counted on to assure long service life for such equipment as brine storage tanks, pumps, valves, filters, evaporators and driers.

Hydrogen Fluoride and Hydrofluoric Acid—Monel is more widely applicable to the handling of anhydrous HF and hydrofluoric acid solutions over a wide range of temperatures and concentrations than any other alloy.

Magnesium Chloride—Because Inconel is free from stress corrosion cracking in boiling magnesium chloride solutions, it has been accepted as a standard material for evaporating magnesium chloride.

Calcium Chloride—For long service life, nickel and Monel linings and flights are used in the large gas-fired rotary driers where wet calcium chloride contacts furnace gases.

Aluminum Chloride—Where aluminum chloride is employed as a catalyst, Monel reaction vessels and piping are often used to resist corrosion from dilute hydrochloric acid formed as a result of hydrolysis.

If your operations with halogens or their compounds seem to indicate the desirability of employing one of the Inco Nickel Alloys, it will be advisable to place equipment orders with your supplier well in advance of scheduled use. Distributors of Inco Nickel Alloys can supply the latest information on availability from warehouse and mill.

*Other materials which are shipped in nickel drums include: acetyl chloride, benzyl chloride, benzoyl chloride, pyrosulfuryl chloride, thionyl chloride, phosphorus trichloride, phosphorus oxychloride, and thiophosphoryl chloride.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, New York

Inco Nickel Alloys



MONEL® • "R"® MONEL • "K"® MONEL • "KR"® MONEL
"S"® MONEL • INCONEL® • INCONEL "X"®
INCONEL "W"® • INCOLOY® • NIMONIC® ALLOYS
NICKEL • LOW CARBON NICKEL • DURANICKEL®



Inorganic Acid Chlorides in Which Satisfactory
Uses of Monel and Nickel Have Been Recorded

Corrosive Media	Monel	Nickel
Aluminum Chloride	Yes	.....
Ammonium Chloride	Yes	Yes
Antimony Chloride	Yes	.....
Arsenic Trichloride	Yes	Yes
Magnesium Chloride	Yes	Yes
Manganous Chloride	Yes	.....
Nitrosyl Chloride	Yes	Yes
Phosphorus Oxychloride .....	.....	Yes
Phosphorus Trichloride .....	.....	Yes
Silicon Tetrachloride .....	.....	Yes
Sulfur Monochloride	Yes	Yes
Sulfuryl Chloride	Yes	Yes
Tin Tetrachloride	Yes	Yes
Titanium Tetrachloride	Yes
Zinc Chloride	Yes	Yes

STOP PIPE-LINE SHUTDOWNS

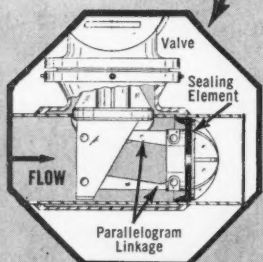
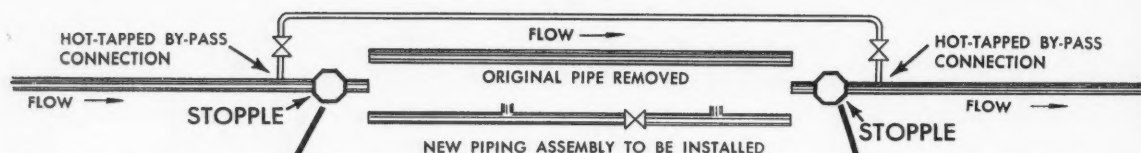
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STOPPLE

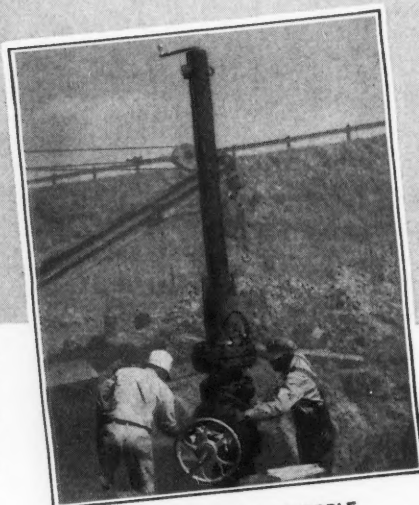
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While making repairs or additions . . .

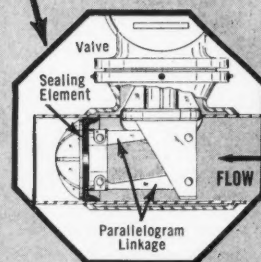
TYPICAL PIPING CHANGE



CUT-AWAY VIEW OF STOPPLE SEALING ELEMENT



WILLIAMSON STOPPLE
HOLDS PRESSURES UP TO 1,000 PSI
DEPENDENT UPON PIPE SIZE, WALL
THICKNESS AND CONDITION.



CUT-AWAY VIEW OF STOPPLE SEALING ELEMENT

Experienced Williamson representatives, factory-trained engineers, are on hand to offer you their assistance in the proper use and installation of Williamson STOPPLES.

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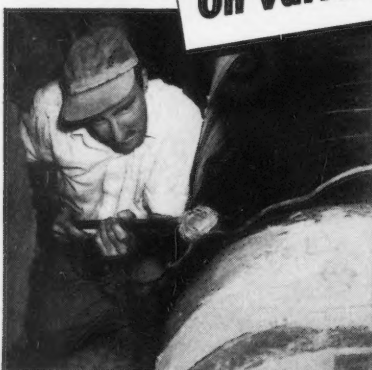
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**gives lasting protection
against pipeline corrosion!**

ON JOB AFTER JOB, Johns-Manville Trantex Tape is controlling corrosion and extending the service life of underground gas and oil pipelines.

Trantex is a durable plastic tape that sticks on contact—bonds tightly to the pipeline. No heat or heavy duty equipment is needed in its application. It is easily applied by hand or by specially developed hand-operated machines. Many users have found that field-applied Trantex Tape speeds coating applications . . . lowers construction costs on both large diameter transmission lines and gas distribution systems.

Trantex Tape is a development of Johns-Manville—a pioneer in the manufacture of Asbestos Pipeline Felts. For further information about Trantex Tape, write for copy of PP-26A, Johns-Manville, Box 60, New York 16, N. Y.



	*V-10	**V-20
Dielectric Strength per mil thickness, Approx.	1,000 V	1,000 V
Insulation Resistance, greater than (ASTM-D-257-49)	100,000 megohms	100,000 megohms
Temperature Limit	200 F	200 F
Adhesion oz. per inch width	30	20
Tensile Strength lbs. per inch	30	56
Elongation at Break	250%	300%

"Trantex" is a black polyvinyl tape. It is available in two thicknesses—

*V-10 is a 10 mil tape for average conditions, and

**V-20 is a 20 mil thickness for use where a more rugged coating is specified, such as to repair enamel coatings.

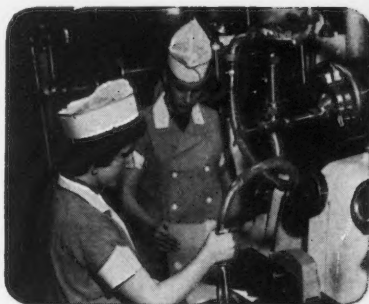


Johns-Manville **TRANTEX** *polyvinyl* TAPE

PROTECTS PIPELINES AGAINST CORROSION

*Here are five ways to use
versatile-flexible*

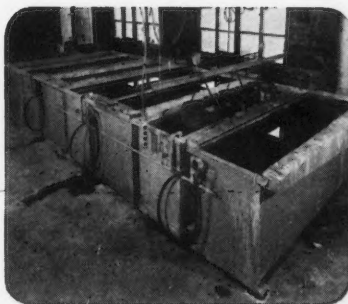
TYGON PLASTICS



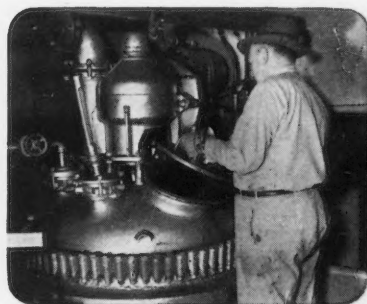
AS TUBING OR HOSE to pipe taste-sensitive liquid foods or corrosive chemicals. Tygon Tubing is glass-clear, flexible as a piece of string, resistant to acids and alkalis, non-toxic, sterilizable, and is made in bores from 1/16" to 2".



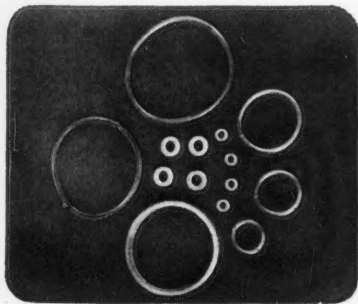
AS A PAINT to protect plant and equipment from attack by corrosive fumes and gases. Applied by brush or spray, Tygon air dries quickly to form a tough impermeable plastic skin that shrugs off acids, alkalis, oils, water and alcohols.



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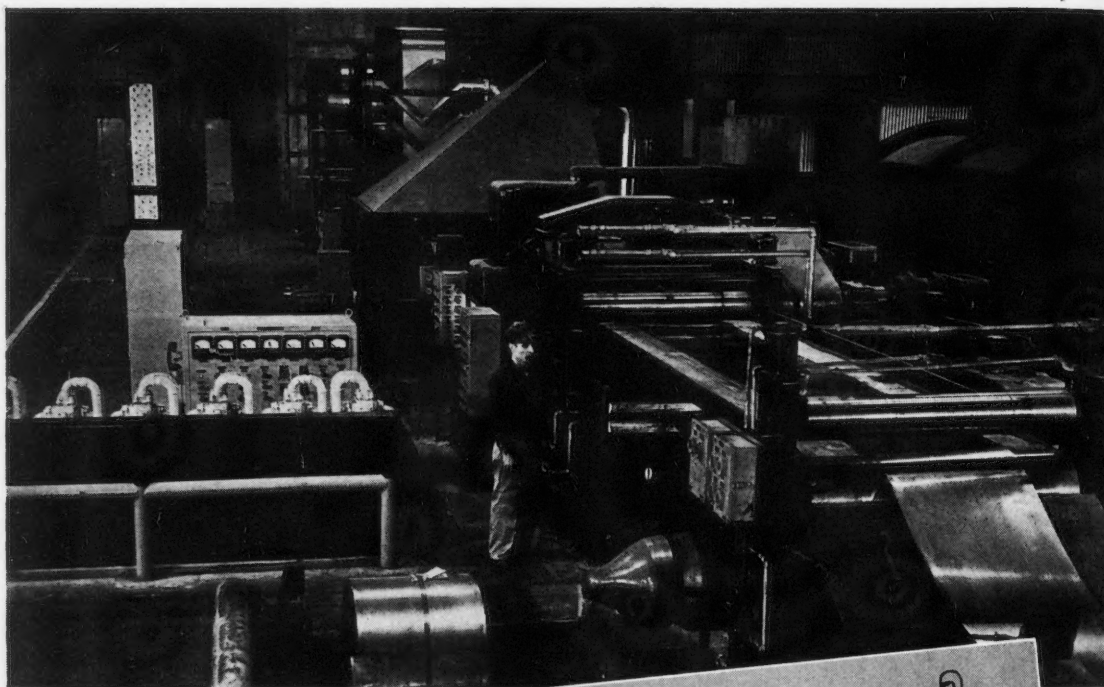
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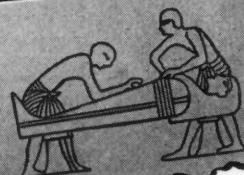
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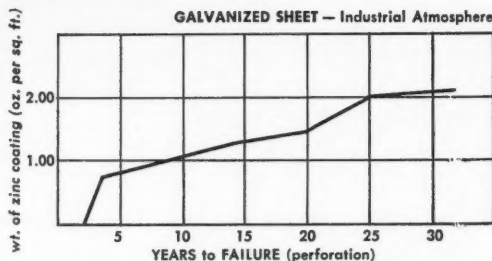


ONE OF the most persistent problems confronting the iron and steel industry is the prevention of corrosion; its persistence stems from the fact that we cannot rid ourselves of the agents which effect the corrosion without, at the same time, ridding ourselves of elements — air and water — which are essential to life itself.

Iron does not occur naturally in the metallic state, but only in combination with oxygen and other elements in the form of ore. The smelting of iron is essentially a process for removing the oxygen from the ore by the application of heat; while rusting is, in essence, the reversion of the metal to its natural state by recombination with the oxygen in the air. The rusting process, being electrochemical in character, is actually far more complicated since the moisture and impurities present in the air play a very important part. There is thus a close relationship between the processes connected with the preservation of organic tissue and the prevention of rust. However, while human beings stave off the decaying or "rusting" of their tissues by nutrition, no means have been developed for "feeding" or regenerating iron and, until such time, industry has adapted the ancient Egyptian practice of "embalming."

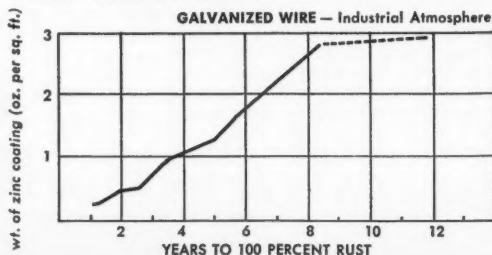
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Topic of the Month

Catastrophic Corrosion Resulting From Vanadium Pentoxide in Fuel Oil Ash

By ANTON deS. BRASUNAS*

Abstract

Catastrophic corrosion resulting from burning fuel oils containing very small concentrations of vanadium is described. Experiments are outlined in which the effects of contamination of fuel oil ash by vanadium and other materials is evaluated after test samples are exposed for varying periods of time at high temperatures. Relative merits of nickel-rich versus nickel-free alloys is mentioned as are experiments involving additives to fuel. Molecular structure of vanadium porphyrin is illustrated and sources of fuel oil containing greatest concentration are listed. 10 references.

AIR-CORROSION of heat resistant alloys at high temperatures is known to be extremely rapid under conditions where surface contamination by certain low melting constituents occurs.^{1,2} The corrosion rate actually accelerates with time³ and reaches catastrophic proportions; corrosion rates actually surpassing a hundred inches per year (approximately three yards per year) are encountered! This poses a critical problem in gas turbines, boiler tubes and other applications where normally heat-resistant alloys are exposed to hot gases resulting from the combustion of certain grades of fuel oil which contain trace amounts of vanadium. Terms such as Rapid,⁴ Accelerated,^{3,5} and Catastrophic have been associated with this form of corrosion. The writer believes that the second term is most appropriate, but the third appears to have more appeal and is most easily remembered.

Although the vanadium content of the fuel oil may be less than a hundred parts per million, it can nevertheless become concentrated to more than 50 percent in the resulting fuel oil ash. These ash particles generally are carried in the gas stream and are deposited on impinged metal surfaces. Instances of oxide dripping from ship boilers and their supports have been observed.

The oxide of vanadium stable in air at elevated temperatures is the pentoxide, V_2O_5 which has a surprisingly low melting point of 1240 F (670 C). Mixtures with certain other metal oxides are known to reduce this melting point to less than 1000 F. Since the corrosion resistance of high temperature alloys arises from the development of an adherent diffusion-resistant barrier which separates the metal from its corrosive environment, the consequences of the formation of a corrosion product which will flow off and leave the metal essentially unprotected, should be quite obvious.

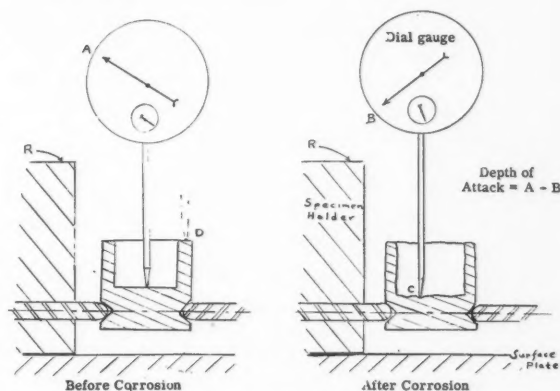


Figure 2—Sketch of device used to determine depth of attack after accelerated oxidation.

Research Efforts

This problem has received considerable attention in this country¹⁻⁵ and abroad⁶⁻¹⁰ during the past five years but remains essentially unsolved. Several theories have been developed to explain the accelerated corrosion rates; one attributes it to the dissociation of the oxide to nascent oxygen⁴ and a sub-oxide, whereas another theory suggests that a molten oxide exists at the metal surface^{3,6} and thus destroys corrosion resistance.

The appearance of a heat resistant alloy after corrosion with and without such contamination is shown

* Associate Professor of Metallurgical Engineering, University of Tennessee, Knoxville.

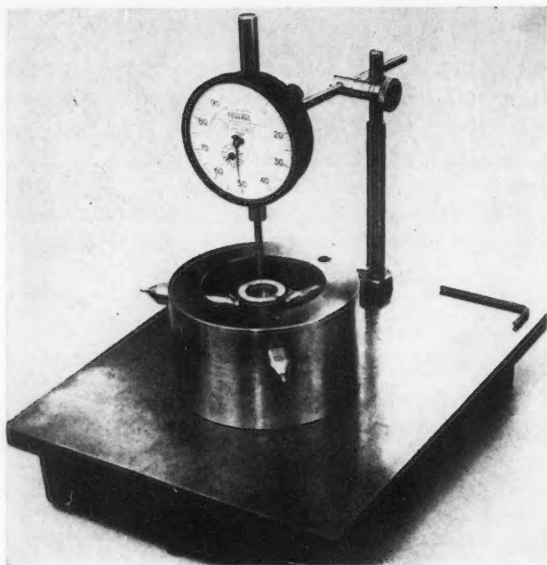


Figure 3—Corrosion depth measuring device.

on the cover (Figure 1) of this issue of CORROSION. The purpose of the V-notch is to retain a reference point on the corroding specimen so that subsequent measurements can indicate the depth of attack. Figure 2 is a sketch which illustrates the measuring technique; readings are taken at reference point R, the top of the specimen D, and the bottom of the cavity C which contains the contaminant. The difference in readings of the dial before and after corrosion gives the depth of attack directly. Figure 3 is an actual photograph of the Corrosion Depth-Measuring device. The second V-notch is used only occasionally to check the measurements; ordinarily specimens are prepared with a single notch.

Source of Vanadium

The numerous trace elements found in petroleum are derived from the decay of animal and vegetable remains as well as from the physical surroundings. Zinc accumulates in the bodies of mollusks and crustaceans, as does calcium in sea shells and animal bones (potassium was obtained from certain sea weeds [kelp] when normal sources were cut off in World War I; iodine is still obtained from kelp). Almost everyone knows that iron is in blood and exists in the form of haematin, the red coloring matter of blood. Chemically, the compound is iron porphyrin, a metallo-organic compound which is very similar to magnesium porphyrin, commonly known as chlorophyll, the green coloring matter of plants. The corresponding vanadium-bearing compound, shown as Figure 4, is oil soluble and may have originated in the blood stream of lower forms of marine organisms.

Certain regions, particularly Venezuela and certain areas of the Middle East were heavily populated with these creatures and the resulting decay products yielded oils unusually rich in vanadium. The following typifies the vanadium-contents of sev-

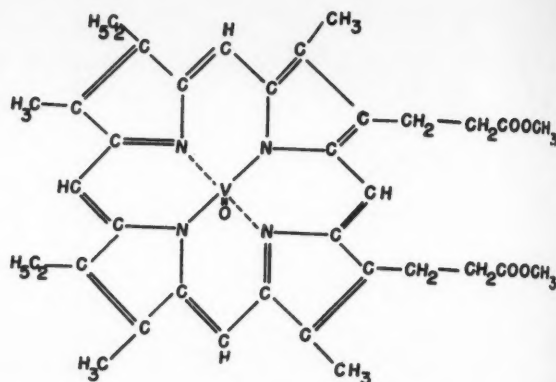


Figure 4—Molecular structure of vanadium porphyrin, an oil-soluble compound which is the cause of the unusual corrosion problem.

eral sources of oil and their resulting ash composition.

Source	V in oil	V ₂ O ₅ in resulting ash
Venezuela	250 ppm	750,000 ppm (75%)
Middle East	30 ppm	80,000 ppm (8%)
Oklahoma	50 ppm	220,000 ppm (22%)
Texas	2 ppm	14,000 ppm (1.4%)

Attempts to find a heat resistant alloy capable of resisting catastrophic corrosion have not met with success. However, nickel-rich alloys³ appear to be more resistant than nickel-free alloys, but their resistance to attack is still far below par. Some success in counteracting the effects of vanadium pentoxide with the use of additives such as CaO, MaO or carbon^{9,10} has developed, but here too, success has been only partially achieved.

The most promising approach to the problem appears to be that of developing an additive to the oil or a porcelain-type coating to be applied periodically to exposed metal surfaces. The former is undoubtedly more desirable from the point of convenience, but a solution to this problem from any viewpoint would be most welcome at this time.

Acknowledgments

This problem is being studied at the University of Tennessee under sponsorship of the U. S. Navy Bureau of Ships whose support is gratefully acknowledged.

References

1. A. deS. Brasunas and N. J. Grant. *Iron Age*, **166**, No. 7, 85 (1950).
2. C. T. Evans. ASTM Publication No. 108, 1950, p. 59.
3. A. deS. Brasunas and N. J. Grant. *Trans. Amer. Soc. Met.*, **44**, 1117 (1952).
4. W. D. Leslie and M. G. Fontana. *Trans. Amer. Soc. Met.*, **41**, 1213 (1949).
5. F. C. Monkman and N. J. Grant. *Corrosion*, **9**, No. 12, 460 (1953).
6. J. H. Meijering and G. W. Rathenau. *Nature*, **165**, 240 (1950) Feb. 11.
7. P. Schlapfer, P. Angwerd, and H. Preis. *Schweizer Archiv für Angewandte Wissenschaft und Technik*, **No. 10**, 29 (1949) Oct.
8. V. E. Fitzner and J. Schwab. *Berg und Huttenmannische Monatshefte*, **1**, (1953) Jan.
9. P. T. von Sulzer. *Schweizer Archiv*, No. 2, 33 (1954) Feb.
10. S. H. Frederick and T. F. Eden. Corrosion Aspects of the Vanadium Problem in Gas Turbines. *Proc. Institution of Mechanical Engineers*, **168**, No. 3, 125-134v (1954) Mar. *Corrosion*, **11**, No. 1, 31-45 (1955) Jan.

Laboratory Evaluation of Inhibitors For Sweet Gas-Condensate Wells*

By P. J. RAIFSNIDER, R. S. TRESEDER and A. WACHTER

IN RECENT YEARS the use of corrosion inhibitors for preventing corrosion in gas-condensate wells has become an accepted and popular practice. Because a very large number of chemicals are potentially useful as corrosion inhibitors in these wells the need developed early for a simple laboratory test method that would indicate the effectiveness of the chemicals before more costly and time-consuming field tests were undertaken. Presented in this paper is a relatively simple method for evaluating inhibitors for sweet gas-condensate wells which has been in use for several years and has proved to be an effective means of predicting inhibitor performance.

Some of the considerations pertinent to selection of an inhibitor for field trial include effectiveness of the additive in reducing corrosion as a function of concentration, its persistence during a period following treatment when the additive is not present in the environment and corrosiveness of the inhibitor concentrate. Consideration of inhibitor persistence is important in connection with maintenance of protection during periods when the inhibitor is not continuously injected or when intermittent addition is desired. Since, in many wells, a concentrated solution of inhibitor is injected down the casing-tubing annulus, it is important to determine if such a concentrate would be corrosive to steel at prevailing down-the-hole temperatures.

The test method developed for determination of inhibitor effectiveness involves placing a steel strip in a mixture of light petroleum fraction and a synthetic aqueous solution under a carbon dioxide atmosphere in a bottle which is rotated end-over-end at constant elevated temperature. With modifications of procedure involving a second period of strip exposure to an uninhibited mixture, this test has been adapted to give information on the persistence effects of inhibitors. The corrosiveness of the concentrated inhibitors at high temperatures is determined by another test, which is a sealed-tube type.¹

Test Methods

Details of the rotated bottle test are as follows: 4 oz glass oil sample bottles are filled with 50 ml kerosene and 10 ml of synthetic salt water (distilled water plus 3% NaCl, 0.1% CaCl₂, 0.03 MgCl₂ and 0.1% acetic acid)*. The bottles are purged with carbon dioxide for five minutes and then preheated to 180 degrees F. After preheating the bottles, the speci-

P. J. RAIFSNIDER—Chemist with Shell Development Company, Emeryville, Cal., where he has been doing corrosion research since 1946. A graduate of University of Wisconsin with a BS in Chemistry in 1941 he was employed during World War II as TNT Area Supervisor by Trojan Powder Company.



R. S. TRESEDER—Chairman of T-1G on Sulfide Stress Corrosion, an active worker on corrosion control and a frequent contributor of technical material to CORROSION and other publications. Mr. Treseder has been engaged in corrosion investigations for more than 12 years. He is with Shell Development Co., Emeryville, Cal., and holds a BS in chemical engineering from University of Utah.



AARON WACHTER—1954-55 president of the National Association of Corrosion Engineers, Mr. Wachter has been active in the association's work for several years. Manager of the Corrosion Department, Shell Development Co., Emeryville, he holds a PhD from University of California.



Abstract

Simple test methods are described for laboratory evaluation of corrosion inhibitors for use in sweet gas-condensate wells. A rotated bottle type test at 180 F with a steel strip in a mixture of kerosene and water is used to screen possible inhibitors. Additional tests under varied conditions are made to evaluate persistence of inhibition. A sealed tube test has been developed to assess the corrosiveness of concentrated inhibitors to steel at well bottom temperatures.

Good correlation has been obtained between the laboratory screening test results and field trial experience.

* Submitted for publication April 23, 1954. Shell Development Co., Emeryville, Cal.

* Actual field samples may be used if desired.

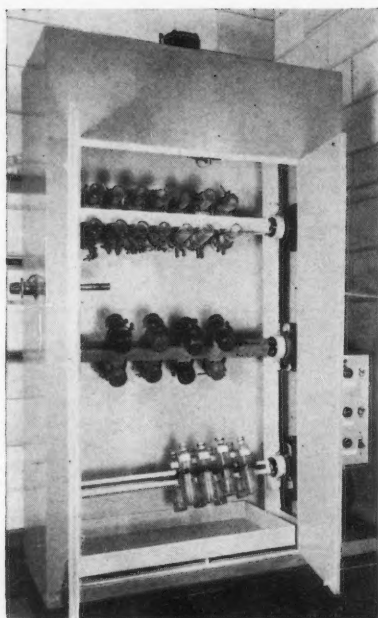


Figure 1—Bottle rotating machine for corrosion tests.

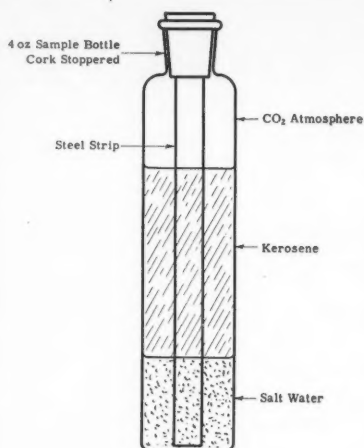


Figure 2—Rotated bottle test assembly.

Figures 1 and 2). The bottles are rotated end-over-end at 60 rpm for the duration of the test period (17 to 20 hours). After termination of the test, the specimens are cleaned by immersing, with gentle agitation, for one minute in concentrated hydrochloric acid containing 5% SnCl_2 and 2% Sb_2O_3 . The specimen then is neutralized immediately in NaHCO_3 solution, rinsed with water and dried. Final cleaning is accomplished using a soft rubber eraser. The corrosion rate is calculated from the net weight loss of the specimen making a correction of 3mg which is the average cleaning loss.

The specimens used in this test and in the persistence test are strips cut from 18-gauge cold-rolled low-carbon steel sheets and are sandblasted before use. The dimensions of these specimens are $\frac{3}{8}$ -inch wide x $5\frac{5}{8}$ inches long. They are weighed to a precision of 0.2 milligram.

The test to evaluate persistence effects of various inhibitors is simply a modification of the procedure described above. Duplicate bottle set-ups are exposed under the standard conditions for one day using an inhibitor concentration above the minimum effective level in both. After one day's exposure, the strip from one bottle is cleaned and weighed and the second strip is re-exposed to uninhibited corrosive for an additional one day period. Corrosion rates for the 1 to 2 day period (called persistence rate in Table 1) are calculated by subtracting the 0 to 1 day weight loss from the 0 to 2 day weight loss. Different inhibitors are rated by comparing their individual persistence rates.

The test to evaluate the corrosiveness of the concentrated inhibitor involves sealing a $\frac{1}{4}$ -inch x 2-inch ground carbon steel specimen in a thick wall glass tube (with CO_2 atmosphere) containing 10 ml of the inhibitor concentrate. The sealed glass tubes are inserted in protective metal containers and placed in an oven thermostated at 250 degrees F. After 24 hours' exposure, the tubes are opened and weight losses of the specimens are obtained.

Test Results

Results of tests simulating sweet gas-condensate corrosion are summarized in Table 2 for a variety of commercial inhibitors. Corrosion rates on uninhibited controls ranged from 48 to 60 mils per year. The standard deviation for control tests was 5 units. Occasional erratic results were obtained when testing at inhibitor concentrations giving only partial inhibition. At effective inhibitor concentration the standard deviation was about 3 units. Arbitrarily, inhibition was considered effective when corrosion rates were reduced to 10 mils per year or less. As indicated by the data in this table, a wide variety of additives

TABLE 1—Persistence of Various Inhibitors

COMMERCIAL INHIBITOR	Concentration, Percent by Weight	Initial Rate, (mils/yr)	Persistence Rate, (mils/yr)
A.....	0.01	6	8
A.....	0.03	6	2
B.....	0.01	5	16
B.....	0.03	3	8
C.....	0.01	7	15
C.....	0.03	5	8
D.....	0.01	9	19
D.....	0.03	9	13
E.....	0.01	7	10
E.....	0.03	12	6
F.....	0.03	1	13

TABLE 2—Laboratory Test Results on Inhibitors For Gas-Condensate Corrosion

ADDITIVE	CORROSION RATE, MILS PER YEAR AT CONCENTRATIONS ¹ OF					
	Per cent by Weight 0.0005	Per cent by Weight 0.001	Per cent by Weight 0.002	Per cent by Weight 0.005	Per cent by Weight 0.01	Per cent by Weight 0.1
NONE (48. to 60.)						
Oil Soluble						
Organic Inhibitor A.....	...	23.	11.	9.	9.	...
Organic Inhibitor B.....	52.	...	10.	...
Organic Inhibitor C.....	...	22.	8.	...	7.	...
Organic Inhibitor D.....	...	13.	8.	...	7.	...
Organic Inhibitor E.....	47.	7.	7.	...	8.	...
Organic Inhibitor F.....	11.	5.	3.	...
Organic Inhibitor G.....	34.	...
Water Soluble						
Inorganic Inhibitor H.....	48.	17.	...	5.	14.	...
Inorganic Inhibitor I.....	28.	...	4.
Organic Inhibitor J.....	8.	5.	...
Organic Inhibitor K.....	...	33.	20.	...	8.	...
Organic Inhibitor L.....	37.	8.
Organic Inhibitor M.....	...	44.	22.	8.	4.	...

¹ Based on hydrocarbon phase.

mens, described below, are inserted and a final short CO_2 purge is made. The bottles then are tightly stoppered with wired corks and placed in a thermostated (180 degree F) bottle rotating cabinet (see

were effective, provided they were present in sufficiently high concentrations.

Comparative data from laboratory tests and field trials on several inhibitors are given in Table 3. As shown by these data, good correlation was obtained between results in the laboratory test and results under field conditions. For example, inhibitor B was found to have a minimum effective concentration of 0.01% (based on liquid hydrocarbon) in the laboratory test. This value, when calculated on the basis of a typical well producing 30 bbl of condensate and 2 bbl of water per million cubic feet, represents a concentration of 0.9 lb per MMCF. Actual field experience showed that 1.0 lb of inhibitor B per MMCF effectively inhibited corrosion.

Since intermittent introduction of inhibitor may be desired in some wells, it is important to have information on persistence of inhibition. Results from persistence tests are summarized in Table 1. As is evidenced by these data, considerable differences in persistence effects exist among the commercial inhibitors evaluated. Comparisons of these test results with field experience have not been made yet.

Since the possibility exists that corrosion of tubing and casing could occur when concentrated inhibitor solutions are injected down the annuli of condensate wells, auxiliary corrosion tests at 250 degrees F were made with steel exposed to such concentrates. Results from these tests are summarized in Table 4, and show that most of the materials evaluated were only mildly corrosive under these conditions. A notable exception was a certain water soluble organic salt which was found to be extremely corrosive in the concentrated form.

Advantages and Limitations

The principal advantages of the rotated bottle corrosion test are its simplicity and speed. Thus, a large number of tests can be made in a short time. For example, it is possible for one person to make 20 tests per day. Since correlation between laboratory results

TABLE 3—Correlation Between Laboratory And Field Corrosion Inhibitor Data

INHIBITOR	MINIMUM EFFECTIVE CONCENTRATION		
	By Laboratory Tests		By Field Test ³ (lb/MMCF)
	Percent By Weight	(lb/MMCF) ¹	
B.....	0.01	0.9	1.0
F.....	0.005	0.5	0.7
H.....	0.02 ²	0.14	0.3
L.....	0.4 ²	2.8	1.2

¹ Calculated on the basis of a typical well producing 30 bbl condensate and 2 bbl water per MMCF.
² Based on aqueous phase.
³ Inhibitor injected continuously into annulus of test well. Performance evaluated by means of well-head coupons (2-3 weeks' exposure).

TABLE 4—High Temperature Corrosion Tests of Inhibitor Concentrates

Conditions:
Carbon steel strip in sealed glass tubes with 10 ml of inhibitor. At 250° F for one day. CO₂ atmosphere.

INHIBITOR	Corrosion Rate, mils/yr
A.....	2.
B.....	3.
C.....	11.
D.....	18.
E.....	8.
J.....	440.

and field experience has been good, this method is believed to be particularly valuable for screening the many materials being offered currently as corrosion inhibitors for sweet gas-condensate wells.

The method apparently has a few limitations. Since cork-stoppered glass bottles are used, pressure must be kept near atmospheric as contrasted with the high pressures (ca. 2000 pounds) often encountered in gas-condensate wells. In addition, special effects such as localized (pitting) attack, and solids deposition (by inhibitor-brine incompatibility) are not fully evaluated by this method.

References

1. R. F. Miller, R. S. Treseder and A. Wachter. *Corrosion*, 10, No. 1, 7-12 (1954), Jan.

Effect of Minor Constituents on the Intergranular Corrosion Of Austenitic Stainless Steels*

By J. J. HEGER* and J. L. HAMILTON**

THE INTERGRANULAR corrosion of the austenitic stainless steels is believed to result from the grain boundary precipitation of chromium carbides which deplete the grain boundary zones of chromium and thus render these zones susceptible to corrosion. The classic work of Bain, Rutherford and Aborn¹ yielded good support to this so-called "chromium depletion" theory of intergranular corrosion. Their results indicated that if the carbon in the austenitic stainless steels could be combined with a strong carbide former such as titanium, or reduced to a very low level, the steels would not be susceptible to intergranular corrosion. The effect of lowering the carbon content is illustrated in Figure 1. In this graph, the carbon content is plotted horizontally and the corrosion rate in mils per 100 hours is plotted vertically. As will be noted, intergranular corrosion by the copper sulfate-sulfuric acid solution is completely prevented when the carbon content of the material is below 0.025 percent.

Unfortunately, at the time Bain, Rutherford and Aborn published their results, commercial production of austenitic stainless steels having very low carbon contents was uneconomical. However, during World War II, improved melting practices permitted these very low carbon steels to be made economically and since that time, commercial production of these grades with .03 percent maximum carbon has increased. Results of the investigations of the intergranular corrosion resistance of these commercial low carbon austenitic stainless steels partially confirm the carbide precipitation theory for intergranular corrosion. However, some of these results do not agree with what might be predicted from a precipitation of chromium carbide and thus new hypotheses have been proposed regarding the precipitation of other minor constituents. The results described here will be those based upon standard laboratory tests, such as the copper sulfate-sulfuric acid or the nitric acid test, which have been developed to determine susceptibility to intergranular corrosion. It must be recognized, however, that such tests may or may not have any relationship to the conditions under which the steels are used commercially.

Figure 2 shows the influence of carbon content on the nitric acid corrosion resistance of 18-8 sensitized for two hours at 1200 degrees F. Carbon content is plotted horizontally and corrosion rate in inches per

Abstract

Results of standard laboratory tests of the corrosion resistance of 18-8 stainless steel indicate the precipitation of minor constituents other than chromium carbide may be significant. Results achieved appear to disagree with those of Bain, Rutherford and Aborn and indicate freedom from intergranular corrosion may be expected only if carbon content is below 0.009 percent, instead of the 0.02 percent they predicted.

Tests showed sensitized 18-8 Mo steel containing 0.03 percent maximum carbon content to be corroded in nitric acid at about the same rates as higher carbon 18-8 Mo steels. Metallographic studies using the corroding solution as an etchant indicated that the delta ferrite-austenite grain boundaries were severely attacked with complete loss of some delta ferrite grains. It is postulated that during sensitization some minor constituent forms at grain boundaries of low carbon 18-8 Mo steels and apparently greater at the boundaries separating the delta ferrite from the austenite.

The need for an instrument capable of making microchemical analyses is mentioned.

month is plotted vertically on a logarithmic scale. These results suggest that as the carbon content is lowered below .030 percent, the corrosion rate decreases to a low and satisfactory level. This behavior agrees with that predicted by Bain, Rutherford and Aborn on the basis of chromium carbide precipitation. However, if the low-carbon stainless steels are heated for longer times in the so-called sensitizing range of temperature, they become susceptible to intergranular corrosion by boiling 65 percent nitric acid, even though the carbon content is as low as 0.017 percent. This effect is shown in Figure 3 and as can be seen from these data, which represent the results of nitric acid tests on 18-8 steels heated for

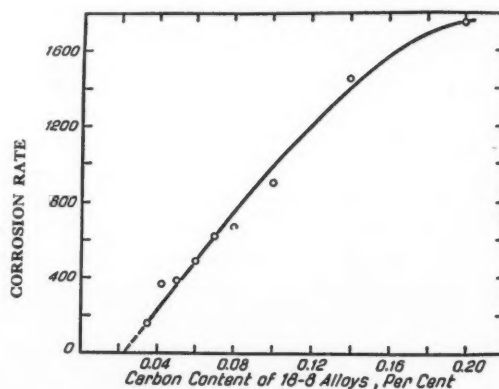


Figure 1—Effect of carbon content on the intergranular in boiling copper sulfate-sulfuric acid of 18 percent Cr-8 percent Ni heated for 1000 hours at the "severest" temperature.¹

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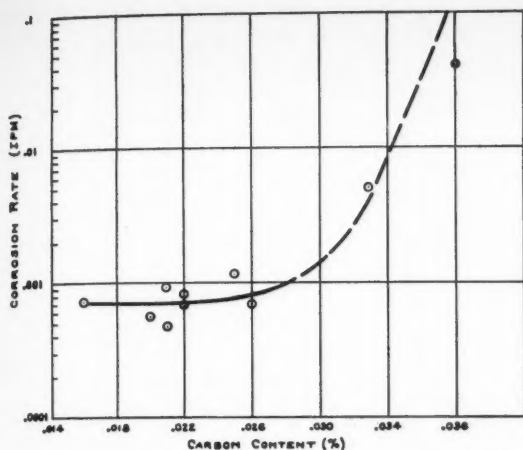


Figure 2—Effect of carbon content on the corrosion rate in boiling 65 percent nitric acid of 18 percent Cr-8 percent Ni heated for two hours at 1200 F.²

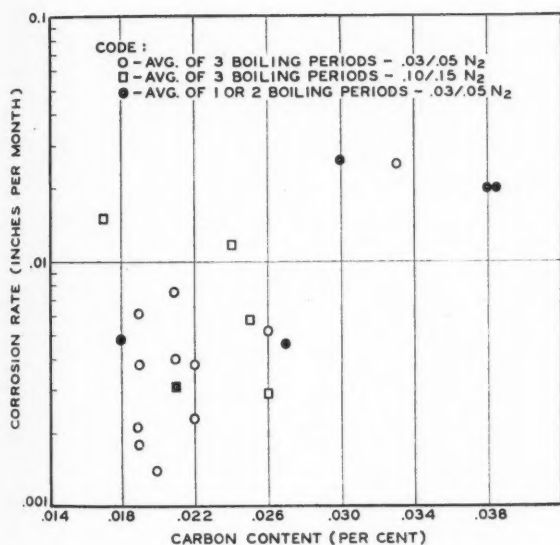


Figure 3—Effect of carbon content on nitric acid corrosion resistance of 18-8 Mo sensitized 24 hours at 1100 F.

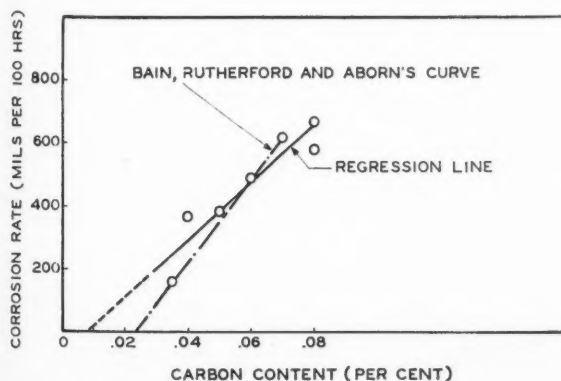


Figure 4—Statistical analysis of Bain, Rutherford and Aborn data showing relation of maximum sensitivity to carbon content. Note: Tests made in copper sulfate-sulfuric acid.

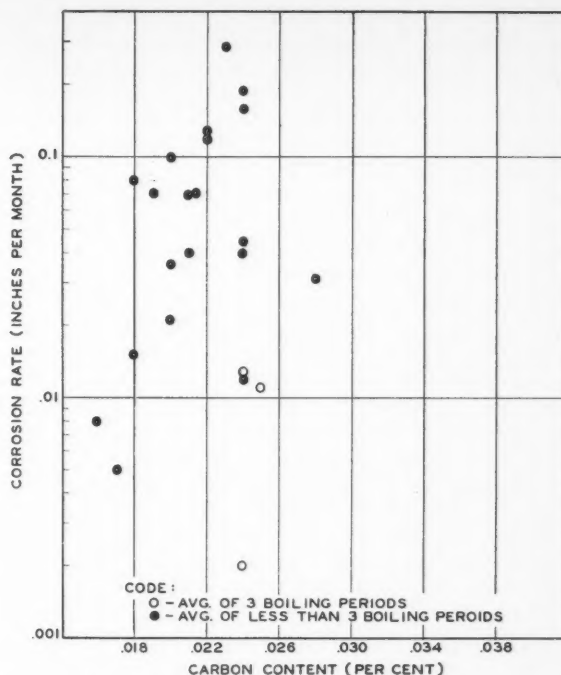


Figure 5—Effect of carbon content on nitric acid corrosion resistance of 18-8 Mo sensitized two hours at 1250 F.

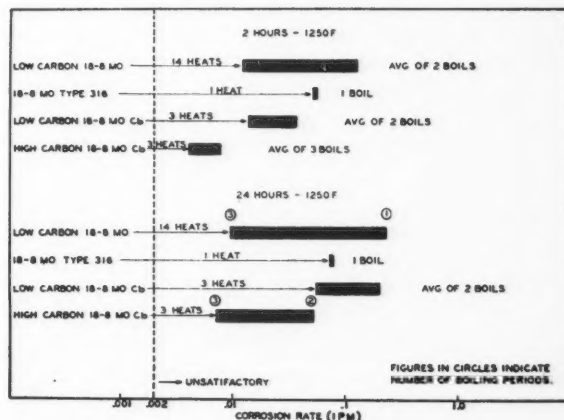


Figure 6—Summary of corrosion tests in boiling 65 percent nitric acid of 18 percent Cr-8 percent Ni, Mo stainless steels.²

24 hours at 1100 degrees F, it appears the carbon content must be lowered to some point well below .015 percent before low corrosion rates can be expected.

These results thus appear to disagree with those of Bain, Rutherford and Aborn, which predict that if the carbon content is below 0.02 percent, intergranular corrosion should not occur. However, if the Bain, Rutherford, Aborn data which were shown in Figure 1 are analyzed by the statistical procedure of linear regression, a mathematical equation can be obtained for the relationship between carbon content and intergranular corrosion rate. The straight line representing this equation is shown in Figure 4, together with the original Bain, Rutherford, Aborn

data and the line which they drew through points obtained by plotting these data. As can be seen, extrapolation of the "regression" line indicates that freedom from intergranular corrosion can be expected only when the carbon content is below .009 percent. Thus, this analysis of the Bain, Rutherford, Aborn data suggests that the intergranular corrosion of the low carbon 18-8 steels is caused by an intergranular precipitation of chromium carbide and that the carbon solubility limit in these steels at about 1050 degrees F is below .009 percent.

The results of intergranular corrosion studies on the low carbon 18-8 steels containing molybdenum cannot be explained by the intergranular chromium carbide precipitation theory. For example, the effect of carbon content on the nitric acid corrosion resistance of 18-8 Mo heated for two hours at 1250 degrees F is shown in Figure 5. Here again carbon content is plotted horizontally and corrosion rate in inches per month is plotted vertically on a logarithmic scale. The corrosion rates shown on this graph are extremely high; indeed, only three of the steels withstood three 48-hour periods in the boiling nitric acid solution. As can be seen, the carbon content appears to have little, if any, effect on corrosion rate. Figure 6 shows the comparative nitric acid corrosion resistance of various austenitic 18-8 Mo steels heated for 2 and 24 hours at severe sensitizing temperatures. Corrosion rates are shown horizontally. As will be noted, the 18-8 Mo steels containing 0.03 percent maximum carbon corroded at about the same rates as higher carbon 18-8 Mo steels. Furthermore, when the carbon content is immunized by additions of columbium, corrosion rates decrease only slightly and what is more puzzling, the low carbon 18-8 Mo Cb steels corrode more rapidly than the higher carbon 18-8 Mo Cb steels.

These results with the 18-8 Mo steels suggest that chromium carbides are not alone responsible for intergranular corrosion and that other minor constituents must have some effect. Buck, Phillips, Heger and Queneau² suggested that sigma phase might be the "minor constituent" that is responsible for intergranular corrosion in the 18-8 Mo steels. Binder³ also believes sigma phase to be the cause for the anomalous behavior of these steels and indeed, he was able to show that sigma phase formed in these steels during sensitization. Although this so-called sigma-phase postulate appears to be logical, caution should be observed before it is accepted because, as yet, direct evidence to support this postulate is lacking.

At first, the results obtained from the corrosion studies of the low carbon 18-8 Mo steels suggested that these steels could not be made with low enough carbon content to insure adequate resistance to intergranular corrosion by the boiling 65 percent nitric acid solution. Fortunately, however, methods may possibly be found for enhancing the intergranular corrosion resistance of these steels. For example, Buck and his associates, prompted by work performed by M. A. Scheil, investigated the effect of heating for two hours at 1625 degrees F prior to the sensitizing heat treatment of two hours at 1250

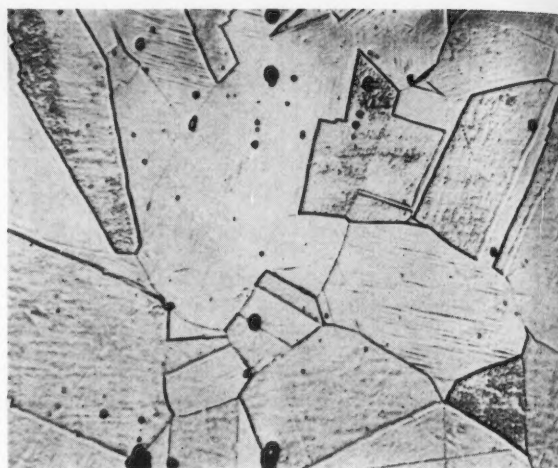


Figure 7—Structure of low carbon (0.024% C) 18-8 Mo heated for two hours at 1250 F.² Etch: Electrolytic chromic acid. X 500.

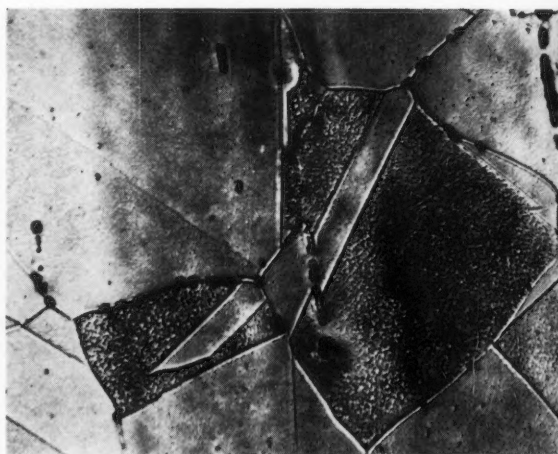


Figure 8—Structure of low carbon (0.024% C) 18-8 Mo heated for two hours at 1625 F, then heated for two hours at 1250 F.² Etch: Electrolytic chromic acid. X 500.

degrees F. When such a dual treatment was employed, they found that 12 of 20 heats responded to the extent that their nitric acid corrosion rates were below the specified acceptable limit of 0.002-inch per month. The reason for the effectiveness of the 1625 degrees F treatment is not yet known.

Another method successfully employed to produce satisfactory nitric acid corrosion rates of sensitized 18-8 Mo material is to heat the material at very high temperatures prior to sensitization. Here again, the reason why a high temperature treatment lowers corrosion rates is not known.

Metallographic studies of samples before and after corrosion testing have often yielded valuable information on the effects of minor constituents as well as on the nature of the corrosion attack. As might be expected, the metallographic studies on the low carbon 18-8 steels confirmed the corrosion test results to the extent that they showed that the sensitizing heat treatments which cause high corrosion

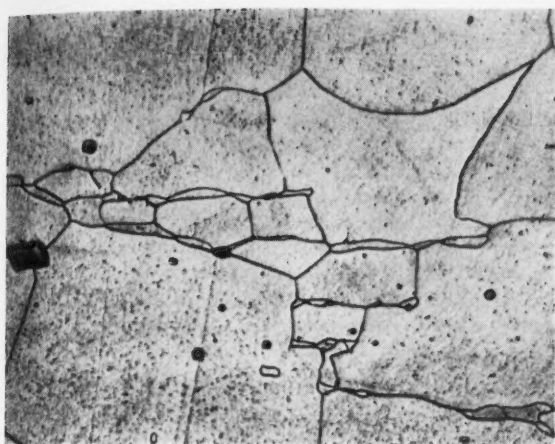


Figure 9.—Structure of low carbon 18-8 Mo (C 0.022, Cr 19.0, Ni 12.40, Mo 2.00) heated for two hours at 1200 F and etched for 16 hours in boiling 65 percent nitric acid. X 500.



Figure 10—Same as Figure 9 but etched for 32 hours in boiling 65 percent nitric acid. X 500.

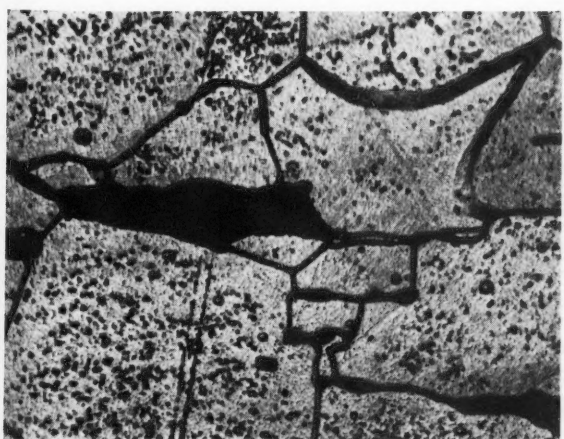


Figure 11—Same as Figure 9 but etched for 48 hours in boiling 65 percent nitric acid. X 500.

rates also resulted in the continuous intergranular precipitation of chromium carbides. However, the interpretation of the structures resulting from sensitizing the low carbon 18-8 Mo steels has been difficult.

As will be recalled, the low carbon 18-8 Mo steels exhibit extremely high corrosion rates after being heated for only two hours at 1250 degrees F. Yet strangely enough, this heating period does not appear to alter the structure of the material. This is well illustrated by Figure 7, which shows the structure of a low carbon 18-8 Mo sample that has been heated for two hours at 1250 degrees F. This structure is no different from that exhibited by a sample in the annealed condition. No evidence of an intergranular constituent can be found, even though this structure is susceptible to intergranular attack by the boiling 65 percent nitric acid solution.

The 1625 degrees F treatment of the low carbon 18-8 Mo steels produced an interesting effect. All heats which exhibited low corrosion rates following this treatment contained a discontinuous grain boundary constituent, as is shown in Figure 8. Conversely, all of the heats which exhibited high corrosion rates did not contain this constituent. Buck and his associates believed this constituent to be sigma phase, but they did not confirm this belief by direct evidence.

As was mentioned previously, heating to very high temperatures prior to sensitization improved the nitric acid corrosion resistance of the low carbon 18-8 Mo steels. This improvement was a marked one, particularly when the initial structure of the material was free from delta ferrite. Metallographic studies using the corroding solution as an etchant yielded information which might lead to a prediction of the role of delta ferrite in these steels. Figure 9 illustrates the structure of a low carbon 18-8 Mo steel that was solution annealed at 2100 degrees F, water quenched and then sensitized by heating for two hours at 1200 degrees F. The etching procedure used for revealing this structure consisted of a 16-hour immersion in boiling 65 percent nitric acid. This procedure constitutes a so-called "micro-corrosion" test. As will be noted, this solution attacked the austenitic grain boundaries and also the grain boundary between the austenite and the delta ferrite areas. Figure 10 illustrates the same area of the specimen after the specimen had been exposed for 32 hours to the boiling 65 percent nitric acid solution. This photomicrograph shows that severe attack has occurred at the delta ferrite-austenite grain boundaries resulting in a complete loss of some delta ferrite grains. Some intergranular attack at the austenitic grain boundaries, general attack and pitting at the carbides within the grains also can be seen. Figure 11 shows the same area after a 48-hour exposure to the boiling 65 percent nitric acid solution. As will be noted, those austenite grains that were completely surrounded by delta ferrite and the delta ferrite grains themselves have disappeared completely. The loss of the delta ferrite grains and of those austenite grains surrounded by delta ferrite are the cause of the high weight losses of the material in the nitric acid test.

These results suggest that during sensitization, some minor constituent has formed at the grain boundaries of the low carbon 18-8 Mo steels. Apparently, the rate of formation of this constituent was greater at the boundaries separating the delta ferrite from the austenite. Thus, a steel containing delta ferrite will exhibit high corrosion rates in the boiling 65 percent nitric acid solution because the delta ferrite grains actually "drop out." When the delta ferrite content of the steel is held to a minimum, lower corrosion rates result.

In summary, the principal minor constituent that influences the intergranular corrosion of the austenitic stainless steels appears to be chromium carbide. However, recent corrosion testing has unearthed enough anomalies, particularly with the low carbon 18-8 Mo steels, to suggest that chromium carbides are not the only minor constituents responsible for intergranular corrosion. Unfortunately, at the present time these "other minor constituents" have not been positively identified. This identification, so necessary

for the understanding of the behavior of the stainless steels, has been hampered by the limitations of the tools at the disposal of the metallurgist. Among the tools required for the identification of minor constituents is an instrument capable of making micro-chemical analyses. This instrument would permit the determination of concentration gradients in the vicinity of grain boundaries and would yield direct evidence on the presence or absence of a chromium depleted zone. Another need is an instrument capable of determining the structure of micro-constituents at the grain boundaries. These two tools, if available, would yield valuable information on the changes that occur in the austenitic stainless steels during sensitizing heat treatments.

References

1. *Transactions, American Society of Steel Treaters*, **21**, 481-509 (1933).
2. *Amer. Soc. Testing Mat. Special Technical Publication No. 93*, pages 56-86 (1950).
3. *Ibid.*, pages 146-182.

Effect of Design, Fabrication and Installation On the Performance of Stainless Steel Equipment*

By JAMES A. COLLINS

DURING the past 25 years stainless steels have developed from an interesting novelty into an indispensable class of engineering materials used by the chemical and allied industries for stills, fractionating columns, reaction vessels, storage tanks, shipping containers, control instruments, pipe, valves and pumps. This indispensability results because these steels possess potential corrosion and heat resistance comparable to the noble metals, gold and platinum and because they can be fabricated readily. However, almost all users have learned—sometimes painfully—that these steels have an “Achilles’ Heel”: their corrosion resistance is vulnerable and can be destroyed and equipment failures may occur prematurely after a very short service life. Performance records show that the successful utilization of stainless steels, and the realization of their full corrosion resistance in chemical process equipment is determined to a considerable degree by the design, fabrication, installation and operation of the equipment. A few case histories are presented of failures in AISI 316 and 347 stainless steel equipment, the reoccurrence of which has been prevented by improvement in design, fabrication or installation. It is hoped these cases will arouse an appreciation of and an active interest in this important problem and will provide information helpful in designing, fabricating, installing and operating stainless steel equipment to take full advantage of their potential corrosion resistance. Neither the evaluation and selection of materials of construction for specific applications nor the modification of process conditions to reduce or control corrosion to permit use of available standard materials are considered in this article.

The excellent corrosion resistance of stainless steels is generally attributed to the presence of a thin, continuous and relatively impervious corrosion-resistant surface oxide film which shields the underlying steel from attack. This film forms practically instantaneously in oxidizing media, after which these steels exhibit high corrosion resistance. This is typical of the passive surface. The film, however, has its limitations and is not a perfect shield, as is well known. For example, in boiling 65 percent nitric acid these steels are attacked at rates as high as 0.0015 to 0.0020-inch penetration per month. In non-oxidizing or reducing media, such as in aqueous hydrochloric or dilute sulfuric acid solutions, the protective surface film either will not form, may form only in scattered local areas, or if present it may

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Abstract

Case histories are presented of failure in austenitic type stainless steel chemical process equipment the recurrence of which have been prevented by improved design, better fabrication or installation. Thermal fatigue, concentration cell corrosion and stress corrosion cracking failures are considered.

be destroyed, with a resulting active surface. In the recent past, occurrence of an active or a passive surface on stainless steel frequently seemed to be rather capricious. For no apparent reason a passive surface might become active and show a high rate of attack and conversely an active surface might become passive and show no corrosion. This now is attributed to the instability of the protective surface film. What had been overlooked or taken to be inconsequential changes in the chemistry of the fluid, the temperature, or the pressure and in the design or construction of the vessel are now recognized to be of major importance. It is apparent, therefore, that the fundamental nature of surface films must be understood as well as conditions for their occurrence and maintenance on stainless steels if maximum corrosion resistance is to be designed into equipment and if it is to be installed and operated in such a way that the resistance is maintained. Only by learning more about actual surfaces and surface reactions can improved knowledge of corrosion mechanisms be expected.

In recent years new experimental techniques and tools have been developed which permit more fundamental studies to be made of surfaces than were possible previously. These include the electron microscope and the electron diffraction camera, the vacuum microbalance, precision volumetric gas adsorption equipment and ultra-microanalytical techniques capable of treating samples as small as 10 micrograms.

*A paper presented at the Tenth Annual Conference, National Association of Corrosion Engineers, Kansas City, Mo., March 15-19, 1954.

The du Pont Engineering Research Laboratory has been actively studying corrosion using these new tools and techniques and much of this work has been published already.^{1,2,3,4,5} The most recent work of the laboratory on surfaces was presented at the Symposium on Surface Properties, sponsored by the New York Academy of Sciences in December, 1953.⁶ Entirely new compositional data on films isolated from AISI 304, 316, 347 and 302B stainless steels and from 14.5 percent silicon iron are reported. A new concept of passive films is proposed and it is shown that the films formed in aqueous media are composed of hydrous mixed metal oxides enriched with silica. Contrary to popular belief, there is no marked enrichment of the passive film in chromium. In Table 1 are a few of the data on passive film compositions of this work.

Some of the other current studies of the du Pont Engineering Research Laboratory include pit type corrosion, oxidation kinetics and relationships between single electrode potentials and surface treatments. Results of these studies will be published in the future. It is hoped that the correlation of the results of these investigations with equipment performance will lead to a marked extension of the life of stainless steel equipment.

Although justifying the name stainless, these steels, like the carbon and low-alloy steels are susceptible to corrosive electrochemical attack. The attack, depending upon the character of its occurrence, may be classed as:

1. General corrosion
2. Concentration cell corrosion
 - a. Aeration cell corrosion (active: passive cell corrosion)
 - b. Ion concentration cell corrosion
 - c. Pitting corrosion
 - d. Crevice corrosion
3. Cracking corrosion
4. Galvanic corrosion
5. Intergranular corrosion (form of galvanic corrosion)

The rate at which the attack progresses is determined by many factors. The principal recognized ones are:

- | | |
|---|-------------|
| 1. Composition
(of corroding medium) | 5. Erosion |
| 2. Temperature | 6. Stress |
| 3. Pressure | 7. Velocity |
| 4. Fretting | 8. Geometry |

TABLE 1⁶

Composition Data on Passive Films Stripped From AISI 304 and 302B Stainless Steels and 14.5% Silicon-Iron

ALLOY	Iron	Silicon	Chromium	Nickel
S. S. 304.....	72.0%	0.6%	18.3%	8.7%
Film.....	27.3	9.9	13.0	9.8
Stoich. Oxide.....	50.0	0.1	13.0	7.0
S. S. 302B.....	69.8	2.7	17.3	8.6
Film.....	30.0	19.0	14.3	8.0
14.5% Si-Fe.....	85.5	14.5	.....	.....
Film.....	37.0	35.0	.....	.....

General corrosion rates can be evaluated quite reliably on the basis of weight loss measurements on samples exposed in laboratory, semiworks or plant equipment and a corrosion allowance provided simply by increasing the metal section thickness beyond that needed for mechanical requirements by an amount sufficient to secure the desired equipment life. On the other hand, local attack resulting from corrosive action of types 2 through 5 above is very difficult to evaluate reliably with coupons. Much study and innumerable investigations have been devoted to the subject of local corrosion and a number of sound general rules have been developed which serve as a guide to prevent the occurrence of this type of attack. These are as follows:

1. Use butt type joints whenever possible. Where fillet or lap joints must be used, make the weld continuous and sound to prevent any fluid getting inside the joint. Avoid riveted or bolted lap joints if possible, Figure 1a.
2. Do not join dissimilar metals or alloys, particularly those widely separated in the galvanic series. If dissimilar metals must be joined, make the larger area of the anodic metal (higher in the galvanic series) and the smaller area (nuts, bolts, rivets, etc.) of the cathodic metal (lower in the galvanic series); if possible, electrically insulate the two dissimilar metals from each other.
3. Baffles, stiffeners, drain nozzles, valves and pumps should permit complete, free drainage and easy washing. (Figure 1b)
4. Avoid sharp corners and recesses where stagnant areas or accumulations of solids could form. (Figure 1b)
5. Support equipment on legs to allow free circulation of air and to prevent the formation of stagnant pools or damp areas. (Figure 1c)
6. Avoid as much as practical turbulent flow and high velocities. (Figure 1d)
7. Avoid use or contact with porous materials such as asbestos, magnesia, wood, etc., which would absorb and hold liquids. Instead, use materials such as rubber or plastics. In the du Pont Company, "Teflon" (tetrafluoroethylene resin) has been found to be particularly good as a gasket or packing material for avoiding or minimizing local corrosion on flange faces and in stuffing boxes.
8. Whenever possible anneal or stress-relieve to reduce residual stresses to the lowest practical level. (In stress relieving heat treatments, the exposure of Type 304, 309, 309S, 316 stainless steels in the temperature range of 900-1500 F should be carefully avoided. Sensitization of these unstabilized steels may occur, resulting in an intolerable reduction in corrosion resistance. If stress relieving treatments must be carried out in this temperature range, tests should be made to determine if the steels will retain sufficient corrosion resistance for the intended specific service, or consideration given to using one of the stabilized type stainless steels, 304L, 309-S-Cb, 316 L, 321, or 347.^{7,8,9})
9. Institute a routine of frequent cleaning of all metal surfaces where sediments accumulate.

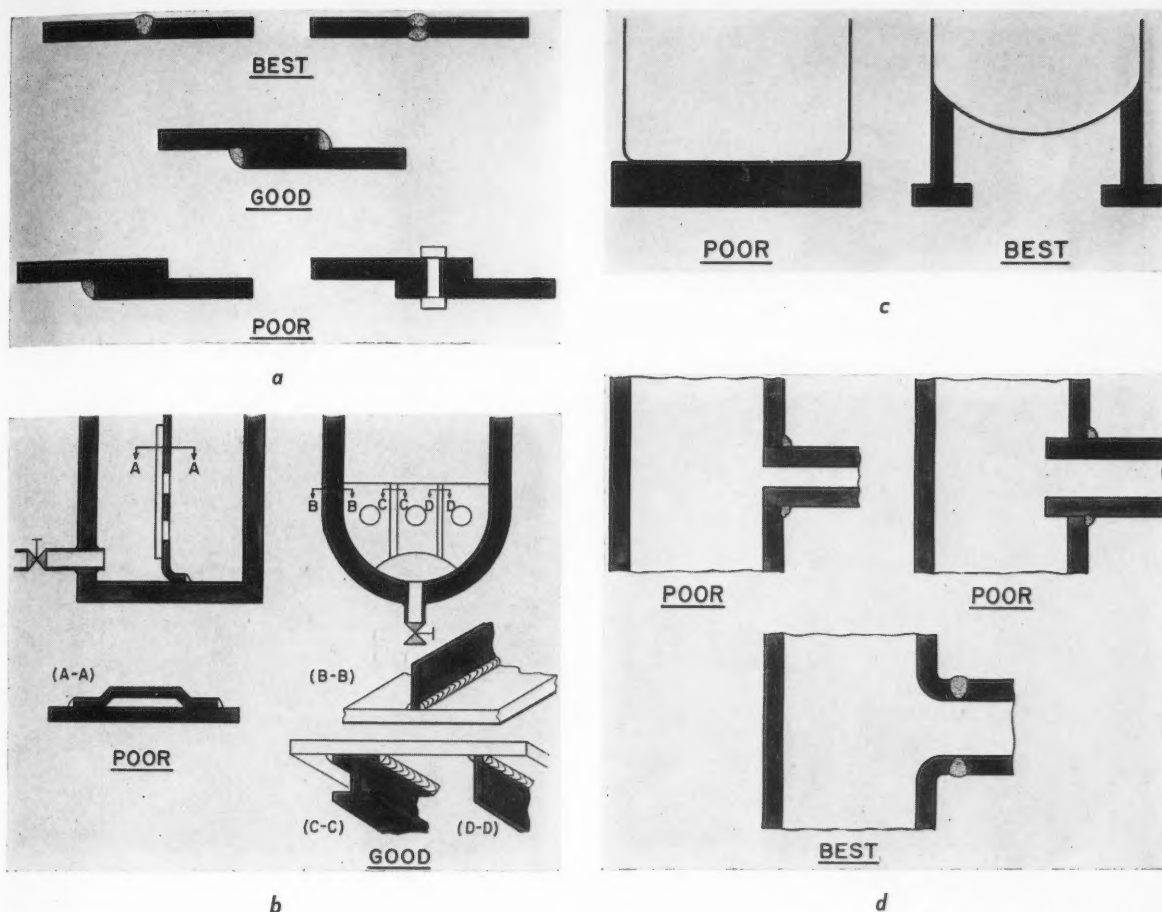


Figure 1—Desirable and undesirable design features for corrosion resistant stainless steel equipment: a) joints, b) baffles, stiffeners, drains, etc., c) supports, d) piping.

Case Histories

Case 1

General and crevice cell corrosion was encountered in some vertical Type 316 stainless steel tubular condensers. These units were condensing vapors and the condensate composition consisted of 10 percent acetic and 10 percent formic acids, balance water, at 70 C and atmospheric pressure. As originally designed there was a slight tube protrusion above the top tube sheet. In construction, the tube rolling operation produced a slight crown in the tube sheet and a slight crevice was left between the tube and the tube sheet. (Figure 2) The trapped process liquor corroded the channel section, the tube sheet and the tubes causing leaks to develop in 1 to 2½ years. Cutting the tubes flush only partially corrected the situation. The liquor around the periphery continued to cause crevice corrosion between the tube sheet and the tubes and to overflow into the outermost tubes causing corrosion of their bores. Complete correction was achieved by altering the rolling operation to keep a flat tube sheet and by rolling tubes tight to the top surface of the tube sheet. The new condensers have been in service more than five years without failures or indications of corrosion.

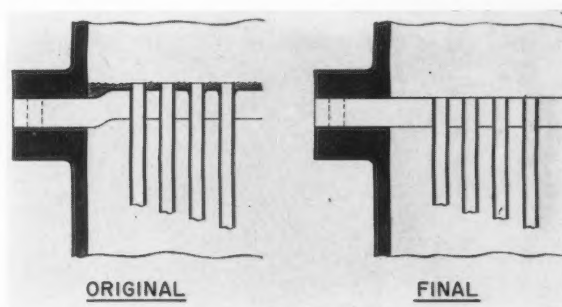


Figure 2—Case 1. Sketches illustrating the design and construction changes which eliminated corrosion in a vertical AISI 316 condenser.

Case 2

A cyclic thermal-corrosion failure occurred after only 6-8 months' service in the top tube sheet and the tube ends of a small waste-heat boiler which was constructed entirely of Type 347 stainless steel. The boiler contained 26 tubes 1½-inch OD, 12 gauge and was used to generate 300 psig steam by extracting heat from 1500-1600 F process gases. Design of the top head and tube sheet is shown in Figure 3. Steam

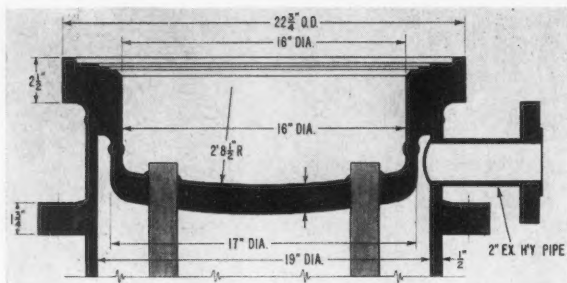


Figure 3—Case 2. Top tube sheet design of AISI 347 waste heat boiler which failed in 6-8 months due to thermal-corrosion.

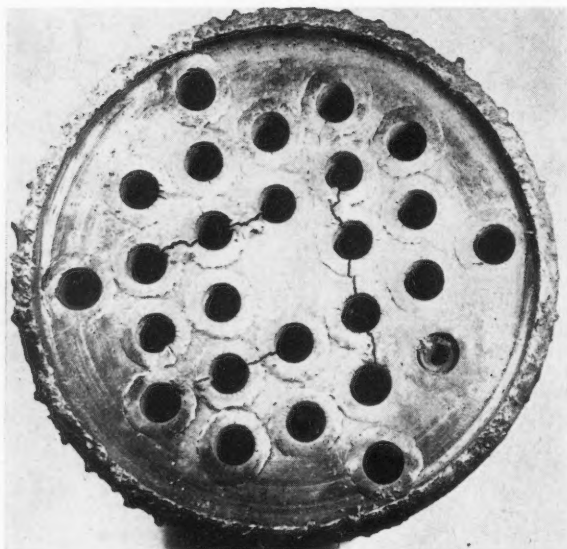


Figure 4—Case 2. View of top tube sheet of AISI 347 waste heat boiler after 6-8 months.

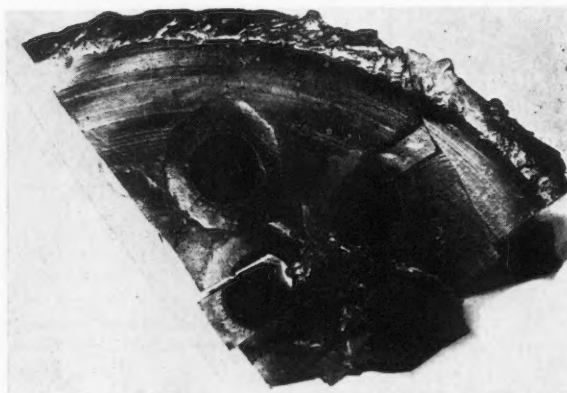


Figure 5—Case 2. Section from the top tube sheet of the AISI 347 waste heat boiler showing the thermal-corrosion cracks in the ends of the tubes.

condensate was used for the boiler feed exclusively except for a short period when untreated river water was used. During this period a considerable amount of salt and scale accumulated. This deposit was cleaned out and the boiler returned to service.

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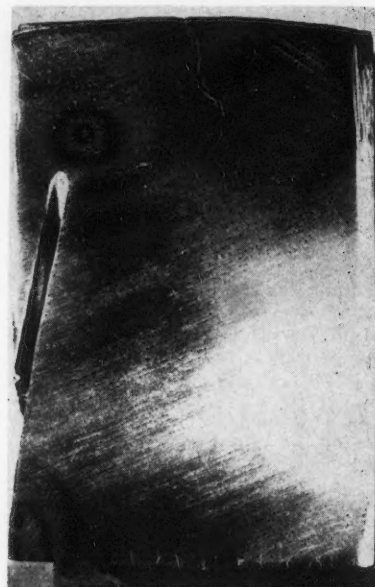


Figure 6—Case 2. Section through the top tube sheet of the AISI 347 waste heat boiler showing the thermal-corrosion cracks in the top surface, and the stress corrosion cracks in the bottom surface. X2.



Figure 7—Case 2. Photomicrograph of the thermal-corrosion cracks in the top tube sheet of the AISI 347 waste heat boiler. Electrolytic oxalic etch. X100.

The condition of the tube sheet and tube ends is illustrated in Figures 4 and 5. It will be noted that the cracks developed around the entire bore of the inner tubes, but on the outer tubes they developed only on the inner portion of the bore. The microstructure of the tube sheet and tubes and nature of

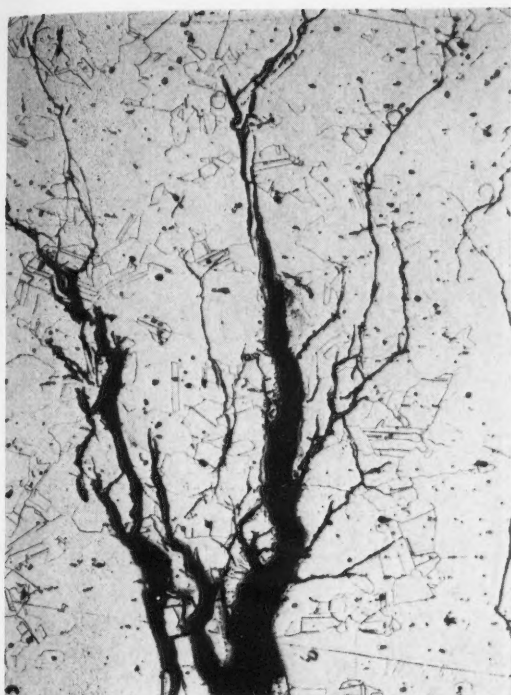


Figure 8—Case 2. Photomicrograph of the stress corrosion cracks in the bottom surface of the top tube sheet of the AISI 347 waste heat boiler. Glycer—regia etch. X100.

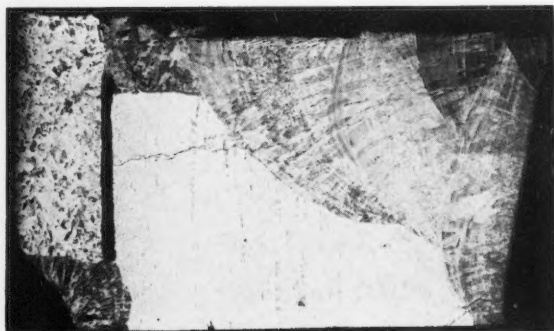


Figure 9—Case 2. Transverse section through the top tube sheet of the No. 1 AISI 316 waste heat boiler. The stress corrosion cracks originated in the crevice between the backup strip on the left and the tube sheet on the right. This is also typical of the No. 3 AISI 316 waste heat boiler. Electrolytic etch. Approx. X40.

the cracks are shown in Figures 6 and 7. These cracks are clearly intergranular and resulted from excessive stresses at high temperatures. Normal service called for this boiler to be "on stream" for 10 days and "off stream" one day. Coming "on stream" the boiler came up to operating temperature in 10-15 minutes and in going "off stream" cooled to ambient temperatures in a similar period. The thermal gradients resulting from this rapid heating and cooling produced the stresses which caused these cracks.

It is interesting to note that stress corrosion cracking in its initial stage of development had occurred on the inside surface of the top tube sheet,

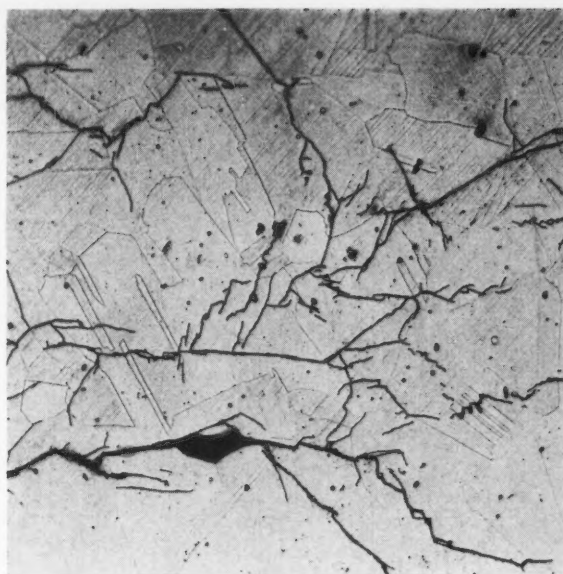


Figure 10—Case 2. Photomicrograph of the stress corrosion cracks in the tube sheets of the No. 1, 2 and 3 AISI 316 waste heat boilers. Electrolytic oxalic etch. X100.



Figure 11—Case 2. Transverse section through the bottom tube sheet of the No. 2 AISI 316 waste heat boiler showing the stress corrosion cracks. Approx. X5.

Figures 6 and 8. This corrosion probably resulted from the chloride-containing salt deposits which accumulated in the boiler during the emergency period when it was operated on untreated river water.

Subsequent to the above boiler failure, three small waste-heat boilers of essentially the same basic design were constructed of Type 316 stainless steel. The important differences were a) the tube sheet thickness was reduced from $1\frac{1}{2}$ inch to $\frac{5}{8}$ inch and b) through an oversight and a change in construction procedure the weld joining the top tube sheet to the top flange was made from the outside only and a back up ring used on the inside. These three boilers

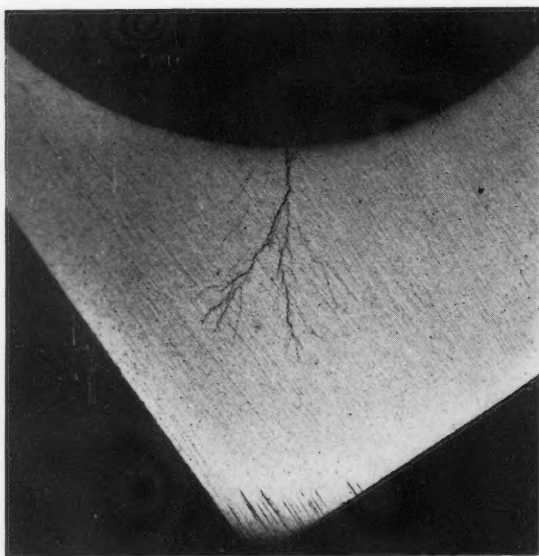


Figure 12—Case 2. Transverse section through a portion of the bottom tube sheet of the No. 2 AISI waste heat boiler showing the stress corrosion cracks. The branching nature of these cracks is clearly shown. Electrolytic oxalic etch, X100.

were installed with a 1-inch thick layer of sillimanite refractory lining on top of the top tube sheet and were operated entirely on steam condensate as follows:

	lb/day
1. Feed	96,100
2. Blowdown (5% continuous)	4,800
3. Steaming Rate (150 psig steam)	91,300
4. Soda Ash, addition	3½
5. Sodium sulfate	2½
6. Trisodium phosphate	¾

The average monthly chloride content of the feed water fluctuated between 10-30 ppm. Daily chloride maxima, however, ran as high as 80 ppm.

Boiler No. 1 failed in one year because of chloride stress corrosion cracking originating in the crevice between the back-up strip and the weld joining the top tube sheet to the top flange. (Figures 9 and 10) Boiler No. 2 failed in two weeks due to chloride stress corrosion cracking originating in the crevices between the tubes and the bottom tube sheet. (Figures 11 and 12) Boiler No. 3 failed in three months due to chloride stress corrosion cracking originating in the crevice between the back-up strip and the weld joining the top tube sheet to the top flange. There was no evidence of thermal-corrosion cracking at the top ends of the tube or on the tube sheet. The refractory lining effectively prevented the occurrence of this type of failure.

One unit was rebuilt eliminating the back-up strip behind the weld joining the top tube sheet to the top flange and particular care was taken to roll the tubes into tight contact throughout the entire cross section of the tube sheet. This unit has now been in service approximately a year and a half and there are no indications of failure. However, stress corrosion cracking seldom, if ever, gives visual warning

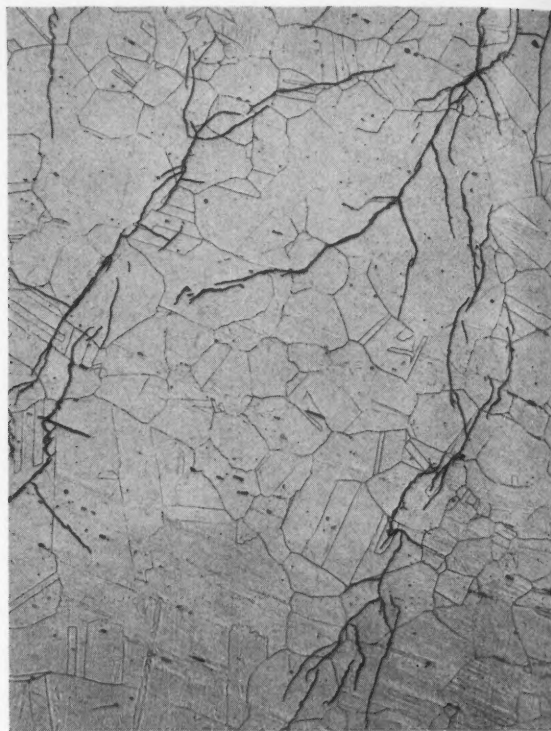


Figure 13—Case 3. Photomicrograph of a section through the wall of the AISI 347 tube showing the stress corrosion cracks. Electrolytic oxalic etch, X100.

of its occurrence before actual failure occurs. Therefore, only time will tell whether this rebuilt boiler will be satisfactory and if the corrective measures taken will be effective.

Case 3

Six leaks developed in an outside installation of welded 6-inch OD x 0.063-inch wall Type 347 stainless steel tubing after approximately 1½ years of service. This tubing handled hot wash water at 90 C and had been covered with standard magnesia insulation to minimize heat loss. The water contained 25-50 ppm of chloride ions and it was assumed that chloride stress corrosion cracking was occurring from the inside. However, the postulate that the failures were internal would not explain satisfactorily why five failures occurred in a horizontal run and only one failure occurred in a vertical run of the tubing.

On examining the cracked sections of the tube it was found that a) pitting and incipient cracking had occurred on the outside in the vicinity of the failures, b) the cracks in the horizontal runs of tubing were entirely on the top half and c) there was no incipient cracking or pitting on the inside. This evidence showed rather conclusively that the cracking was developing from the outside. Chemical analyses showed that the magnesia insulation contained 0.009 percent water-soluble chloride ion and the deposits adhering to the tube in the cracked areas contained 0.004 to 0.06 percent water-soluble chloride. With this information it became apparent that rain

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had penetrated into the magnesia insulation, dissolving the chloride and deposited it on the stainless tube where it caused chloride stress corrosion cracking. The insulation was removed from the tube, and in the subsequent 2½ years no failures have occurred. Figure 13 is a photomicrograph illustrating the intragranular and branching character of the cracks produced by this form of corrosion.

A second interesting case of chloride stress corrosion cracking was encountered in several Type 316 stainless steel distillation columns insulated with magnesia. These units operated at atmospheric pressure and 100 to 130 C. Other equipment in the building was washed down periodically with brackish river water and the insulation of these columns inevitably became soaked. The requirements for stress corrosion cracking were thus provided, temperature above 50 C, chlorides above 50 ppm and stress. The latter was present as residual stress because the columns were used as fabricated without heat treatment. The magnesia insulation was replaced with Foamglas which was effectively sealed against water penetration and all chloride stress corrosion cracking was eliminated.

Case 4

In a number of Type 316 stainless steel vertical condensers, severe cracking was occurring near the upper end of the tubes after periods of 6 to 12 months. Hot process gases entered the top of these units at 155 C and condensed liquors left the bottom at 60 C. Fresh water, containing 100 ppm of chloride ions provided the cooling in a counter current flow entering the bottom at 35 C and leaving at the top at 80 C. Examination revealed the top tube sheet was not adequately vented, resulting in a vapor space and the build up of a salt deposit on the tubes at the liquid-vapor interface. Concentration of the chloride ion occurred in these deposits and caused the corrosion cracking.

The situation was corrected by 1) providing adequate venting of tube sheet to insure complete wetting and the elimination of all vapor pockets, 2) changing the flow of cooling water from counter current to co-current and 3) increasing the flow of cooling water to hold an inlet temperature of 35 C and an exit temperature of 55 C. These changes were made several years ago and have virtually eliminated the chloride stress corrosion cracking. It is no longer considered a maintenance problem on this equipment. Figure 14 is a photomicrograph showing the intragranular branching cracks so typical of this form of cracking corrosion.

Case 5

A Type 316 stainless steel centrifugal wash compartment failed by corrosion after two years' service. The wash contained dilute sulfuric acid, hydrogen sulfide and carbon disulfide at ambient temperatures. Pitting due to concentration cell corrosion was found on the bottom of the compartment under deposits of debris and sediment. These accumulations of foreign matter resulted because the container bottom was flat and the drain nozzle was on the side slightly above

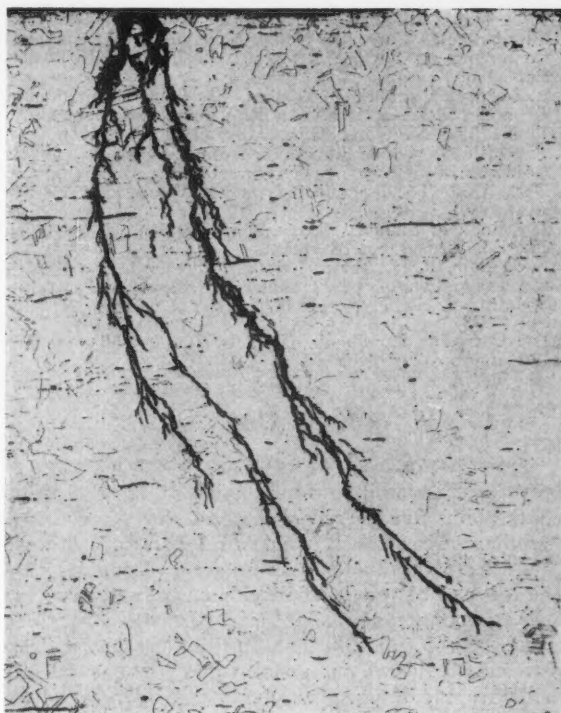


Figure 14—Case 4. Photomicrograph of a section through the wall of one of the tubes of the AISI 316 condenser, X100.

the bottom. These washers have been modified to have a sloped bottom with a flush drain nozzle at the lowest point. Several years' service have accumulated on these modified washers without any corrosion failures.

The theme of this paper has been the importance of design, fabrication, installation and operation on the corrosion resistance of stainless steel equipment. Corrosion resistance is not secured simply by using stainless steels as the materials of construction. With such an approach the results may be very disappointing and costly. The apparent corrosion resistance of a stainless steel vessel may be little or no better than one of low-alloy steel. To realize the full potential corrosion resistance of stainless steel in process equipment it is necessary that the equipment be "tailored" to the corrosion resistance requirements of the stainless steels. To do this the men designing, fabricating, installing and operating the equipment must have an appreciation of the fundamental nature of surface films on stainless steels and the laws which set forth the conditions for their occurrence and maintenance.

References

1. E. M. Mahla and N. A. Nielsen. Passivation of Stainless Steels. *Trans. Electrochemical Soc.*, **89**, 167 (1946).
2. E. M. Mahla and N. A. Nielsen. A Study of Films Isolated from Passive Stainless Steels. *Trans. Electrochemical Soc.*, **93**, No. 1, 1 (1948).
3. E. M. Mahla and N. A. Nielsen. An Oxide Replica Technique for the Electron Microscope Examination of Stainless Steels and High Nickel Alloys. *J. Applied Physics*, **19**, No. 4, 378 (1948).

4. E. M. Mahla and N. A. Nielsen. Application of the Electron Microscope to Corrosion Studies. Pittsburgh International Conference on Surface Reactions, 1948, p. 60. Corrosion Publishing Company, Pittsburgh, Pa.
5. E. M. Mahla and N. A. Nielsen. Carbide Precipitation in Type 304 Stainless Steel—An Electron Microscope Study. *Trans. Amer. Soc. for Metals*, 43, 290 (1951).
6. T. N. Rhodin. Oxide Film Composition Studies. New York Academy of Sciences, Symposium on Surface Properties, Dec., 1953. To be published in the Proceeding of the Academy.
7. The Book of Stainless Steels, edited by Ernest E. Thum. 2nd Ed. 1935. Pages 388-404.
8. E. C. Bain, R. H. Aborn, J. J. B. Rutherford. The Nature and Prevention of Intergranular Corrosion in Austenitic Stainless Steels. *Trans. Amer. Soc. Steel Treathers*, 21, 481-509 (1933).
9. The Corrosion Handbook, edited by H. H. Uhlig. 1st Ed. 1948. Pages 161-164, 1019, 1104.

DISCUSSIONS

Discussion by Frank N. Speller, Pittsburgh:

Recently I examined four stainless steel dyeing plants about five years old. One of these had many corroding areas all at welds and porous castings. The other plants had shown no serious trouble. The main difference was in the welds and illustrates in a striking manner the effect of open stainless steel fissures in chloride solutions. In this case the crevices were mostly in welds; usually due to poor fusion. Evidently the oxygen supply became exhausted in these crevices and the passive film destroyed. The oxygen concentration differential and the active-passive potential started rapid corrosion accelerated by the high cathodic-anodic area ratio. A stainless steel nut was found lying loose on the bottom of a dye tank. I noticed marked rusting under the nut. When the position of this nut was shifted rusting again developed although there was no evidence of corrosion in other parts of the system in which all the welds (that could be seen) were smooth and sound in contrast to the other case where the welding practice was evidently defective. Several other factors affect the localized corrosion in this case but this is not the time to discuss these in detail or the remedies that appear promising.

Question by John F. Eckel, Knolls Atomic Power Laboratory, General Electric Co., Schenectady:

Has your experience shown that when stainless steel tubes are tightly rolled into stainless steel tube

sheets, thermal cycling will cause crevices to open in these joints?

Reply by J. A. Collins:

In reworking one of the small Type 316 stainless steel waste heat boilers referred to in the paper, particular care was taken to roll the tubes into the tube sheets as carefully and as tightly as possible. Our aim, of course, was to have no crevice between the tubes and the tube sheets. We have no method for determining how well this was accomplished. After 18 months' service, failure occurred due to chloride stress corrosion cracking, which originated in the crevice between the tubes and the tube sheets. We have no way of knowing whether these crevices were present after the rolling operation or if they developed while the boiler was in service. It is my opinion that it is impractical to depend upon good (perhaps nothing short of perfect) tube rolling to prevent the occurrence of chloride stress corrosion cracking in the crevices between tubes and tube sheets in heat exchange units where the operating conditions of temperature and pressure could cause concentration of the chloride ion.

Question by H. Howard Bennett, Socony Vacuum Company, Inc., Paulsboro, N. J.:

Has a chloride concentration been established below which stress cracking of austenitic stainless steels does not occur?

Reply by J. A. Collins:

I know of no minimum chloride ion concentration below which stress corrosion cracking of austenitic stainless steels will not occur. Chloride stress corrosion cracking is not alone a function of chloride ion concentration. It is related also to temperature and time and the nature of the chloride salt. In our experience with chloride-containing cooling waters, we have no record of stress corrosion cracking for indefinite periods for temperatures below 50 C and chloride ion concentrations below 50 ppm. We have, however, heard of the occurrence of chloride stress corrosion cracking in austenitic stainless steels by brine solutions such as magnesium chloride in which the chloride ion concentration was appreciably below 50 ppm.

Corrosion Aspects of the Vanadium Problem In Gas Turbines*

By S. H. FREDERICK⁽¹⁾ and T. F. EDEN⁽²⁾

Introduction

THE GAS TURBINE may be made to burn a variety of fuels, for example, pulverized coal, waste gases, and peat and coal-tar products have either undergone testing or are being tested. Marine gas turbines, however, must be capable of burning cheap residual fuels which are readily available at existing bunkering stations if they are to compete with existing prime movers. Such fuels consist of distilling or cracking plant residues cut back to a suitable viscosity with distillates.

As a recent paper by Lloyd and Probert (1950)⁽³⁾ has shown, the problems arising in the use of such fuels have been largely overcome so far as combustion is concerned. Unfortunately the combustion of residual fuels yields sulphur oxides and inorganic ash in addition to the normal products of hydrocarbon combustion, and it is these products that are responsible for most of the corrosion of gas turbine materials. Smaller quantities of sulphur oxides are also produced when distillate fuels are burnt, but the production of a harmful inorganic ash in any quantity is abnormal because ash-forming constituents usually remain in the still bottoms during the fractionation process.

Messrs. C. A. Parsons were one of the first to encounter blade fouling on using residual fuels, and details of their work are recorded in papers both by Bowden and Jefferson (1949) and Hughes and Voysey (1949). They reported serious blade fouling in a 500 hp gas turbine in as little as 8 hours when residual fuel was used, but made no reference to blade corrosion. An account of the testing of a 500 hp experimental gas turbine by Messrs. John Brown and Co. in 1949 is given by Bucher (1950). In this case the use of a residual fuel for approximately 300 hours resulted in the blades of the first two stages being coated with an appreciable quantity of fused ash and some corrosion of the blades had occurred.

Later work has shown that the difference in behavior of the ash deposits found in the two turbines can be accounted for by the fact that in the second case the operating temperature was above the threshold temperature of attack. In 1949 little information was available regarding the behavior of gas turbine materials when subjected to the action of molten fuel ashes containing vanadium compounds. It was accordingly decided to carry out a series of laboratory

Abstract

The effect of V_2O_5 and mixtures of V_2O_5 and Na_2SO_4 on turbine fouling and corrosion is discussed. Laboratory tests have shown that none of the commercially available alloys is immune from attack when these mixtures are molten, that is, at temperatures above 650 degrees C. Nickel base heat resisting alloys of the Nimonic type offer higher resistance to attack than the austenitic steels and some degree of protection is afforded by electro-deposited coatings of chromium.

Steels and heat resisting alloys are not attacked to any significant extent at temperatures below the melting point of the ash, but copper base alloys suffer considerable corrosion at temperatures as low as 500 degrees C.

A detailed investigation of the effect of additives on the corrosion rate of V_2O_5 - Na_2SO_4 ashes indicates that corrosion can be considerably reduced and that such a method of approach is promising. Suitable additions may be made by a mixture of oil or water soluble materials with the fuel, by suspension in the fuel, or by separate injection into the combustion chamber with the object of reducing corrosion and deposition.

Laboratory corrosion tests, using ash additives such as ZnO , Al_2O_3 and kieselguhr, have shown that the rate of attack can be greatly accelerated if the additive is present in certain critical proportions, but when this is exceeded, corrosion is considerably reduced. With MgO , however, no such increase in attack was noted. Rig tests have confirmed some of the beneficial effect of additives.

corrosion tests on a limited number of alloys, particularly those steels used for the blading of the 3500 hp Pametrada gas turbine. The results of this work, and those of other workers, notably Schlapfer, Amgwerd and Preis (1949) and of Evans (1950), indicated that there was little hope of obtaining materials suitable for gas turbine components that would be immune from the corrosive action of vanadium-containing fuel ash. The authors have little experience of the behavior of ceramics, but it is known that they tend to absorb molten ash. Under such conditions it is anticipated that their properties would be impaired.

Laboratory Corrosion Tests

A study of the behavior of heat resisting alloys in contact with V_2O_5 at elevated temperatures can be carried out by means of simple laboratory tests. Such tests have been frequently condemned as unrealistic and bearing no relationship to engine conditions.

Whilst the authors agree that the results of laboratory tests should be treated with some reserve, especially as regards actual rate of corrosion, experience has shown them to be almost indispensable guides to the direction which should be followed by the more time consuming rig and engine tests. In material testing they serve to indicate which alloys are the most promising and worthy of more detailed

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The ms of this paper was first received at the Institution on 1st October, 1952 and in its revised form as accepted by the Council for Publication on 10 June, 1953.

(1) Senior metallurgist, Pametrada Research Station.

(2) Senior chemist, Pametrada Research Station.

(3) An alphabetical list of references is given in the appendix.

investigation and allow those of little or no resistance to attack to be abandoned in the early stages of the work. Such tests have shown their value in investigating the possible effects of various dosages of corrosion inhibitors.

No attempt was made to cover a wide range of alloys, the work being confined to those which were of immediate interest to Pametrada. The creep-resisting austenitic steels FCB(T) and G18B which have been used for the blading of the Pametrada 3500 hp gas turbine, together with Nimonic 80, were selected for investigation, typical analyses of these alloys being given in Table 1.

Before this work was completed the results of a comprehensive series of tests covering a wide range of materials was published by Evans (1950), and it was considered that any extension of the work to cover additional materials would have resulted in unnecessary duplication.

The preparation of large quantities of fuel ash in the laboratory is not a practical proposition and it was decided to use synthetic ashes composed of V_2O_5 and Na_2SO_4 . The results of preliminary work had shown that the presence of Na_2SO_4 greatly accelerated the rate of attack of V_2O_5 , reaching a maximum with the addition of about 10 percent Na_2SO_4 . An ash of this composition was used throughout the work dealing with the effect of additives, and as a basic composition for the corrosion tests.

Test pieces in the form of $\frac{1}{8}$ -inch thick disks cut from $\frac{5}{16}$ -inch diameter ground bars were placed in fused silica crucibles and sufficient powdered ash added to ensure complete immersion when molten. Heating was carried out in a laboratory electric muffle furnace, and on completion the disks were sectioned, one half being mounted in Bakelite and prepared for micro-examination. The extent of corrosion was determined from the reduction in thickness that had occurred, final measurements being made with the aid of a microscope stage micrometer.

A consideration of the work carried out by Schlappfer and others and by Evans (1950) indicates that tests conducted under laboratory conditions show remarkably close agreement, as regards the relative behavior of different alloys, irrespective of the method of testing. The rates of corrosion, however, are liable to vary considerably from one type of test to another and a comparison of the behavior of different alloys must be restricted to those tested under identical conditions.

To determine whether any protection against the corrosive action of V_2O_5 could be obtained by the use of either nickel or chromium coatings, a series of tests was carried out using disks cut from mild steel bars which had electro-deposited coatings of both nickel and chromium. The coatings were ground after deposition so that a deposit of known thickness was obtained which in this case was 0.004 inch.

It was intended to carry out the majority of the corrosion tests at a temperature of 650 degrees C which corresponds to the maximum inlet temperature of the Pametrada gas turbine. Initial tests, however, showed that only those ashes containing Na_2SO_4

were molten at 650 degrees C and a minimum temperature of 670 degrees C was adopted (the melting point of pure V_2O_5 given in the literature ranges between 680 degrees C and 690 degrees C, but it is known to vary according to the mode of preparation).

Details of the tests carried out at 670 degrees C (1238 degrees F) and 820 degrees C (1508 degrees F), together with the results obtained are given in

TABLE 1—Composition of Alloys Used in Laboratory Corrosion Tests

	PERCENT		
	FCB(T)	G18B	Nimonic 80
Carbon.....	0.12	0.40	0.09
Manganese.....	1.50	0.80	0.30
Nickel.....	11.0	13.0	Balance
Chromium.....	17.5	13.0	20.0
Tungsten.....		2.5	
Molybdenum.....		2.0	
Titanium.....			2.5
Columbium.....	1.2	3.0	
Aluminum.....			0.5
Iron.....			0.4

TABLE 2—Scaling Tests in V_2O_5 Only

MATERIAL	Temperature, Deg. C.	Time, Hours	Section Thickness, Inches		Percent Reduction
			Before Test	After Test	
FCB(T).....	670	50	0.096	0.092	4.2
	670	200	0.0945	0.087	7.9
G18B.....	670	50	0.109	0.101	7.4
	670	200	0.083	0.076	8.4
Nimonic 80.....	670	50	0.0925	0.090	2.7
	670	200	0.091	0.088	3.3

TABLE 3—Scaling Tests in $V_2O_5 + 10$ Percent Na_2SO_4

MATERIAL	Temperature, Deg. C.	Time, Hours	Section Thickness, Inches		Percent Reduction
			Before Test	After Test	
FCB(T).....	670	50	0.116	0.106	8.6
	670	200	0.116	0.078	32.8
	820	50	0.117	0.062	47.0
G18B.....	670	50	0.093	0.076	18.3
	670	200	0.106	0.048	54.5
	820	50	0.108	0.028	74.1
Nimonic 80.....	670	50	0.101	0.100	0.99
	670	200	0.087	0.081	6.9
	820	50	0.087	0.065	25.1

TABLE 4—Scaling Tests in $V_2O_5 + 30$ Percent Na_2SO_4

MATERIAL	Temperature, Deg. C.	Time, Hours	Section Thickness, Inches		Percent Reduction
			Before Test	After Test	
FCB(T).....	670	50	0.099	0.086	13.1
	670	200	0.0945	0.060	36.5
G18B.....	670	50	0.0865	0.068	21.4
	670	200	0.083	0.036	56.6
Nimonic 80.....	670	50	0.109	0.094	13.9
	670	200	0.091	0.082	9.9

Tables 2, 3 and 4. A consideration of these results indicates that:—

- 1) The rate of scaling increases with increasing temperatures.
- 2) Scaling increases with time.
- 3) The addition of Na_2SO_4 to V_2O_5 markedly increases the rate of attack.

Tests carried out with Na_2SO_4 alone showed that there was no appreciable attack and with mixtures of V_2O_5 and Na_2SO_4 the rate of attack was almost negligible at temperatures below the melting point of ash.

Schlapfer and others arrived at similar conclusions and reported that the attack ceased in a reducing atmosphere. This suggests that in addition to any possible solvent action that vanadium-bearing ashes possess, corrosion may be due to the V_2O_5 acting as an oxygen carrier, thus allowing progressive oxidation to occur in the presence of air. If corrosion is due to the formation of metal vanadates the absence of oxygen will prevent the continuous formation of metal vanadates.

It will be noted that under all conditions the molybdenum-bearing G18B was the most heavily attacked and this was also reported by the Swiss workers. They considered that the increased rate of attack shown by molybdenum-bearing steels was due to the formation of MoO_3 which sublimes from the scale leaving it in a weakened state. Such scales readily exfoliate and expose fresh metal surfaces to attack.

Microstructures

A micro-examination of the alloys after contact with molten ashes showed that in addition to general wastage, some of the test pieces had been subjected to a pronounced scouring action. It was most noticeable in those tests which produced a high rate of corrosion, and typical examples will be seen in Figures 1a and b. These show the effect on FCB(T) and G18B after 200 hours at 670 degrees C in an ash consisting of $\text{V}_2\text{O}_5 \times 10$ percent Na_2SO_4 . This treatment did not have the same effect on Nimonic 80, but scouring occurred when it was tested at 820 degrees C. (Figure 1c.)

FCB(T) was the only alloy to suffer from intergranular attack, the depth of intergranular penetration increasing with increasing rate of attack. The effects of both time and temperature are shown in Figures 1a, d and e.

Effect of Nickel and Chromium Coatings

The effects of an ash consisting of $\text{V}_2\text{O}_5 \times 10$ percent Na_2SO_4 at a temperature of 670 degrees C on electrodeposited coatings of nickel and chromium are shown in Figures 1f, g, h and i. Nickel offered little resistance to attack. After 200 hours the deposit had begun to disintegrate, particularly where the coating had been attacked from both sides owing to preferential corrosion of the mild steel. Chromium behaved in a rather different manner, protection of the base metal failing, not owing to wastage of the coating but to its thermal cracking and subsequent exfoliation.

As the thermal expansion of chromium is only about 60 percent that of ferritic steels and 40 percent that of austenitic steels it is unlikely to be of any use as a protective coating.

After testing a large number of different types of coating Evans found that a useful degree of protection was obtained by 'chromizing' and in view of the authors' experience with electrodeposited chromium such a process may find limited application in gas turbines.

Low Temperature Ash Corrosion

It has already been stated that the attack of heat-resisting steels and nickel chromium alloys is negligible at temperatures below the melting point of the ash and can be ignored in the majority of cases. Unfortunately this is not the case with copper base alloys such as are commonly used in gas turbine heat exchangers.

Evans reported that after 168 hours at 538 degrees C in ash obtained from fuel oil of Venezuelan origin, aluminum bronze was heavily attacked below the level of the ash, slight attack having also occurred above the ash level.

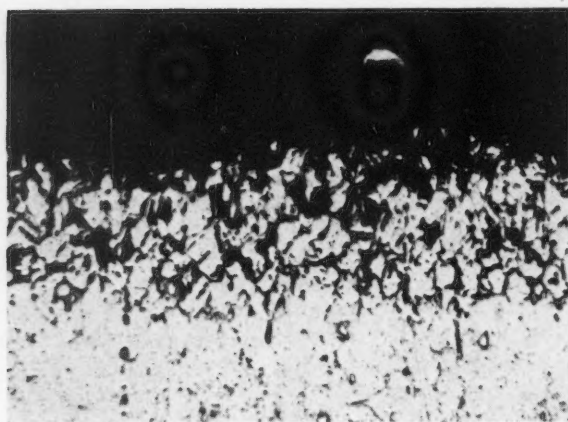
As the heat exchanger of the Pametrada gas turbine is tubed with $\frac{3}{8}$ -inch outside diameter 22 SWG 7 percent aluminum bronze (Yorcalnic), it was decided to investigate the effect of an ash consisting of $\text{V}_2\text{O}_5 + 10$ percent Na_2SO_4 on such material at temperatures of 400 and 500 degrees C (752 and 932 degrees F). One-inch lengths of Yorcalnic tube, $\frac{3}{8}$ -inch outside diameter, 22 SWG were half immersed in ash contained in fused silica crucibles.

After 300 hours at 400 degrees C no appreciable attack could be detected, but severe attack occurred after only 100 hours at 500 degrees C (Figure 1j). This test was continued for a further 200 hours and a micro-examination was carried out on a section cut from the corroded end of the tube, that is, that part of the tube which had been completely immersed in the ash. It will be seen from Figure 1k, that the outer surface of the tube was attacked in preference to the bore and measurement showed that the wall thickness had been reduced approximately 10 percent. The difference in rate of attack between the bore and outside of the tube was probably due to differential aeration.

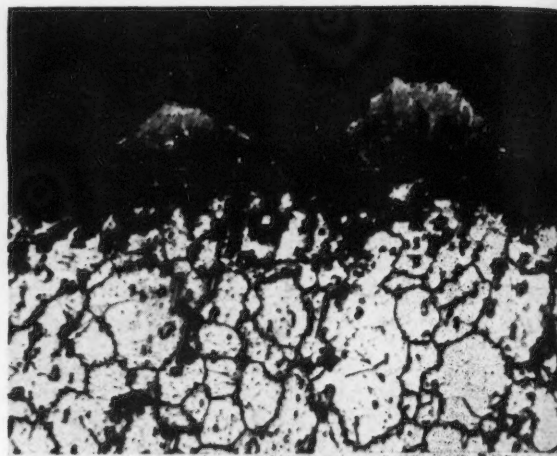
At both 400 degrees C and 500 degrees C, the ash composed of $\text{V}_2\text{O}_5 + 10$ percent Na_2SO_4 was completely dry and although it 'caked' slightly after 300 hours at 500 degrees C, it readily powdered when disturbed.

TABLE 5—Composition of Copper-Base Alloys Used in Low Temperature Corrosion Tests

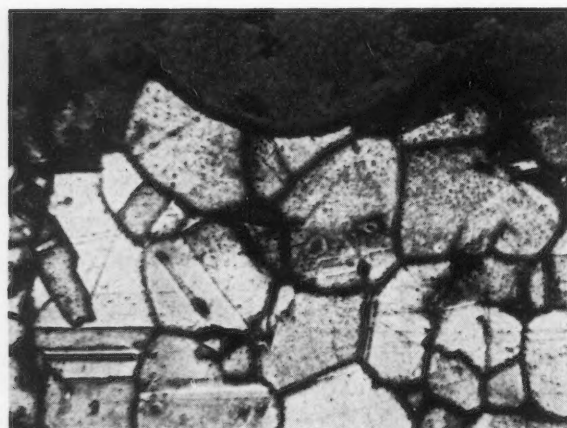
SAMPLE	Cu	Al	Fe	Ni	Cr	Mn
PFS.....	93.03	6.87	.....	.....	.....	0.11
PFT.....	91.25	7.05	0.86	0.98	.....	0.02
PFU.....	90.77	7.05	.....	1.99	.....	0.22
PFV.....	90.92	6.68	2.44	.....	.....	0.14
PFW.....	87.06	6.79	3.06	2.90	.....	0.15
PFZ.....	91.81	6.77	.....	.....	.....	1.37
PEX.....	Nominally 7 percent Al+Cr remainder Cu					0.10
PEX2.....						0.24
PFY3.....						0.37
PFY2.....						0.60
PFY4.....						0.88



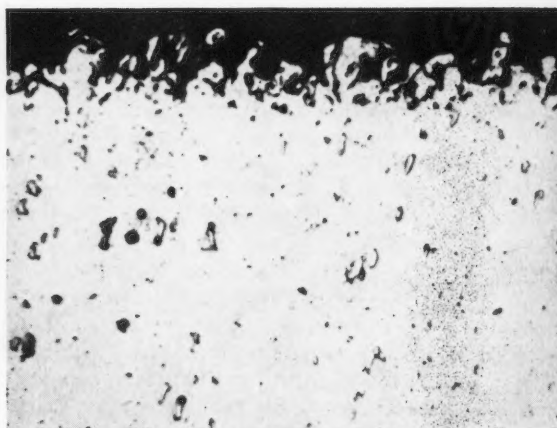
a—FCB(T), 670 degrees C, 200 hours. x250



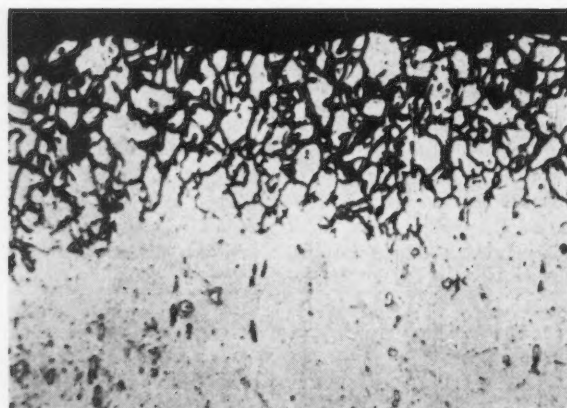
b—G18B, 670 degrees C, 200 hours. x250



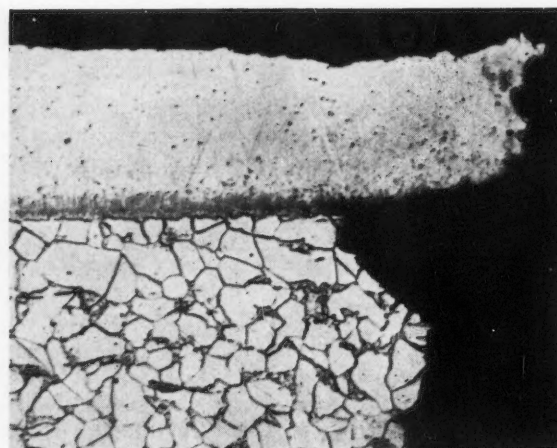
c—Nimonic 80, 820 degrees C, 50 hours. x250



d—FCB(T), 670 degrees C, 50 hours. x250

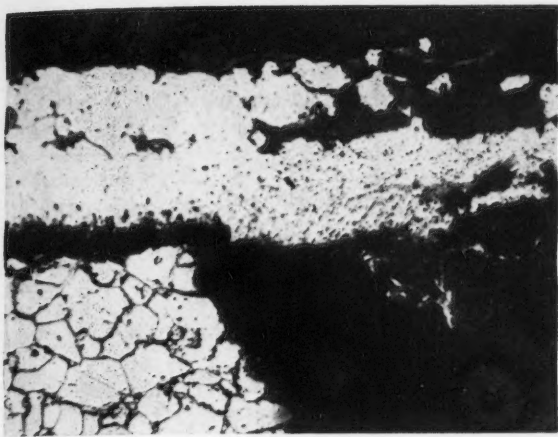


e—FCB(T), 820 degrees C, 50 hours. x250

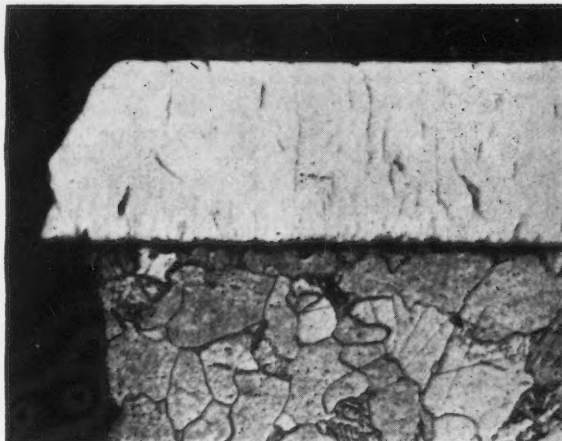


f—Nickel coating, 670 degrees C, 50 hours. x250

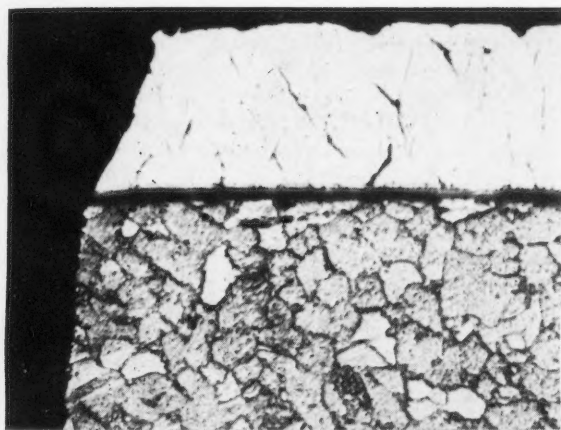
Figure 1—Typical examples of corrosion due to ash composed of V_2O_5 + 10 percent Na_2SO_4 .



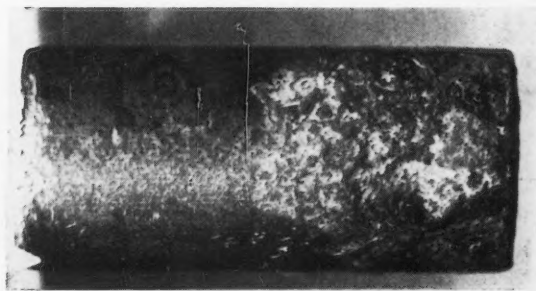
g—Nickel coating, 670 degrees C, 200 hours. x250



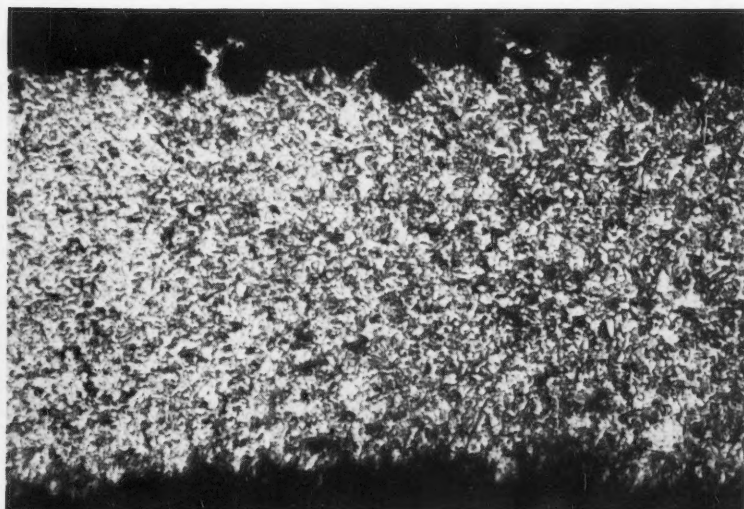
h—Chromium coating, 670 degrees C, 50 hours. x250



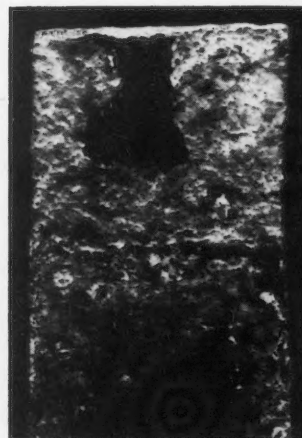
i—Chromium coating, 670 degrees C, 200 hours. x250



j—Aluminum bronze heat exchanger tubing, 500 degrees C, 100 hours. x3



k—Section through corroded part of tube shown in Figure 1j. x100



l—Aluminum bronze strip tested in pre-fused ash, 500 degrees C, 350 hours. x3

Figure 1—Continued

In addition to the work on samples of heat exchanger tube, tests were carried out on a series of aluminum bronze sheets having the compositions shown in Table 5, both sheets and analytical data being supplied by the British Non-Ferrous Metals Research Association (BNFMRA). Two ashes were used, both containing $V_2O_5 + 10$ percent Na_2SO_4 . In one case, however, the ash was fused at 850 degrees C and re-ground to a fine powder prior to test. It had been suggested that an ash prepared in this manner would more closely simulate engine conditions as any ash finding its way into a heat exchanger would have been fused in passing through the combustion zone. The tests were carried out in the same way as those for the tubing, small strips 1-inch long \times $\frac{3}{8}$ -inch to $\frac{1}{2}$ -inch wide being exposed to the ashes for 350 hours at 500 degrees C. Alloys PFS, PFT, PFX2, PFX and PFV were all attacked more or less severely by the fused ash, a typical example being shown in Figure 2. The attack by the unfused ash was rather more widespread and only the chromium-containing alloys PFY3, PFY2 and PFY4 offered any degree of resistance. When the alloys were attacked by both fused and unfused ashes there was no noticeable difference in degree of corrosion. In both series of tests chromium proved to be the most beneficial addition to aluminum bronze.

All the tests on aluminum bronze at 500 degrees C showed a greater degree of oxidation of the specimens above the level of the ash than would have been expected had V_2O_5 been absent, indicating that vapour phase attack had occurred.

An extensive amount of work, much as yet unpublished has been carried out by a large body of investigators to determine the effect of vanadium-bearing ashes on metals, alloys and ceramics. A study of this work has convinced the authors that there does not exist, at the present time, any metal or protective coating that will indefinitely withstand the attack of molten fuel oil ash containing a high percentage of vanadium. Gas turbines have been run on residual fuels (usually on a selected one, the vanadium content of the ash never being quoted) with gas temperatures not exceeding 650 degrees C. In such cases corrosion by fuel ash may well be never encountered but it would be unwise to run a gas turbine on a residual fuel known to be high in vanadium and with metal temperatures above the melting point of the ash without making some attempt to prevent the ash from entering the turbine in a molten and undiluted state.

Suppression of Corrosion

This can be brought about by additions to the fuel or to the gas stream of compounds which either affect the physical nature of the ash to reduce its adhesive powers or chemically affect the vanadium compounds to produce a relatively inert substance.

With this object in view the effects of magnesium oxide, aluminum oxide, kieselguhr (mainly silica, often known as diatomaceous earth), vermiculite and zinc oxide were investigated. Zinc oxide was known to have given promising results when used by other workers.

Batches of weighed quantities of ash mixture (90 percent V_2O_5 , 10 percent Na_2SO_4) and the additives to be tested were roughly mixed by stirring with a spatula and then brought into intimate contact by grinding in a mortar and pestle. Cylindrical metal corrosion specimens of known weight in silica crucibles were covered with the powdered mixtures and placed in an electric muffle furnace. Tests were carried out at 700 degrees C for 100 hours and during the majority of the tests, sufficient air was passed through the furnace to change the furnace atmosphere every few minutes. After cooling, the specimens were descaled by the sodium hydride process and reweighed.

The results of these tests (some of which are shown graphically in Figure 2) indicate that, with the exception of magnesium oxide and vermiculite (the latter on two of the three alloys tested only) these additives are capable of bringing about a marked increase in the amount of attack at certain proportions. In Figures 3a and b, this effect is shown for kieselguhr and zinc oxide-ash mixtures on G18B and compared with the straightforward behavior of magnesium oxide in Figure 3c. Apart from this peculiarity, however, all the additives tested were effective in reducing corrosion when employed in sufficiently high concentration: zinc and magnesium oxides were especially effective.

It was noticed that those additions which brought about a marked reduction in corrosion also produced non-molten ashes which did not readily adhere to the metal specimens. With increasing dosages this dryness proceeded through the stage of friable solids in which the fused ash was acting rather like a cement to that of truly free running powders. Of the compounds investigated, silica, in the form of kieselguhr, seemed to be the least effective from this point of view, although it would be unwise to make any firm conclusions, as the experiments did not include an investigation of factors such as particle size range and previous history of the refractory powders. These variables were kept as constant as possible by using materials from the same source in each test. It can be concluded with some certainty, however, that the use of such additions to an ash will not only reduce corrosion but should also be of some benefit in alleviating engine fouling: to what degree can be determined only by engine tests.

It is not proposed to discuss in any detail whether the reduction in corrosion is brought about by the formation of inert compounds between the additives and vanadium pentoxide or by withdrawal of the ash mixture from contact with the metal surfaces by absorption. The available evidence is too slight to allow of anything much more satisfactory than conjecture. It is suspected that true chemical combination is being encountered in the case of zinc and magnesium oxides, but that alumina, silica and vermiculite are acting mainly as absorbent diluents.

When, in later experiments with alumina and vermiculite, air was not passed through the furnace and corrosion proceeded in a still atmosphere, it was found that both the extent of and the critical concentration for increased attack were liable to variation.



Figure 2

Materials

The atmosphere attacked The

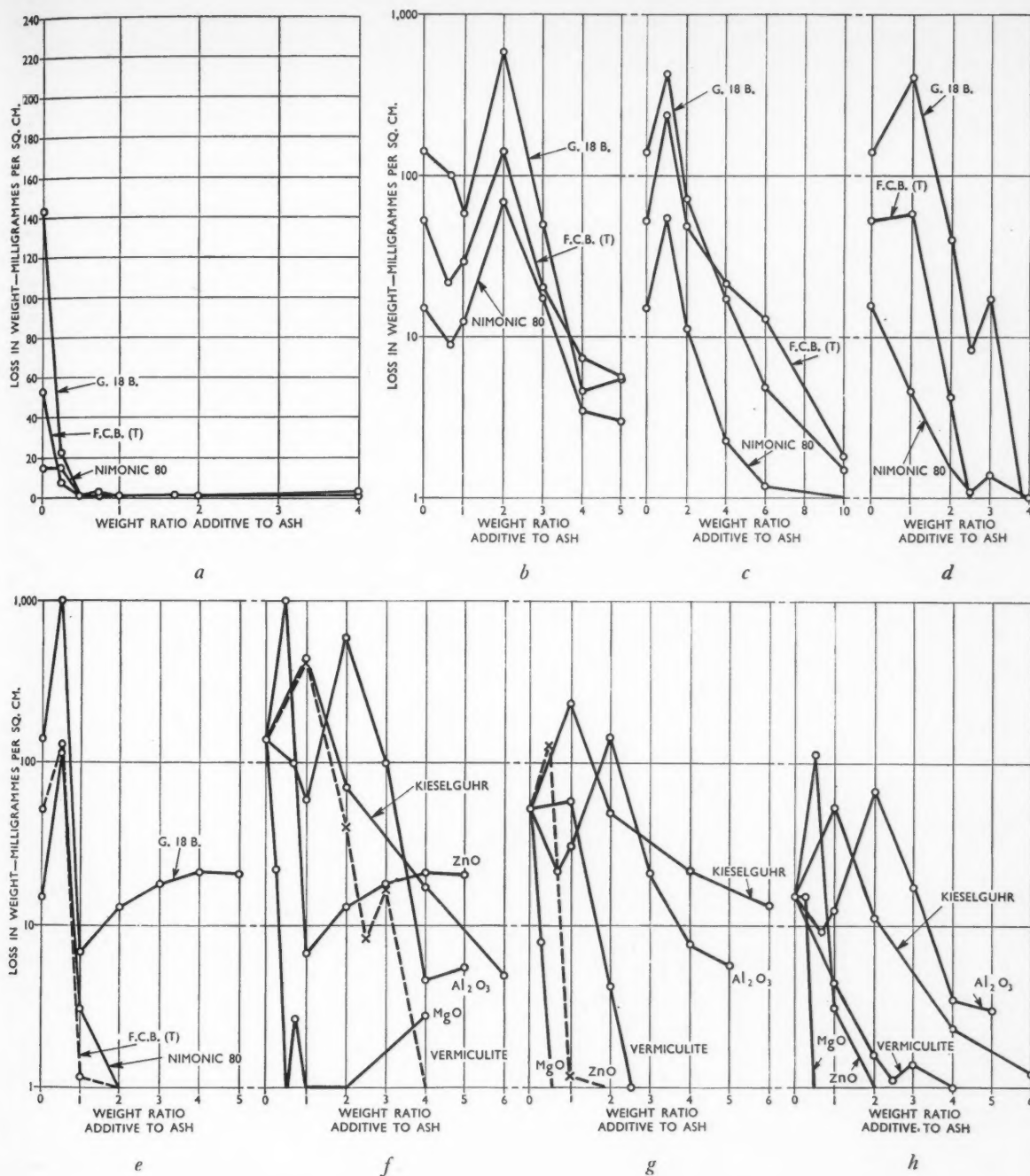


Figure 2—The effect of various materials on scaling. Time, 100 hours; Temperature of tests, 700 degrees C; Ash composition: $V_2O_5 + 10$ percent Na_2SO_4 .

Materials: a—MgO. b—Al₂O₃. c—Kieselguhr. d—Vermiculite. e—ZnO. f—Various additives on G18B. g—Various additives on FCB(T). h—Corrosion of Nimonic 80.

The results in Table 6 show that the effect of a still atmosphere has been to reduce considerably the attack on G18B with 1/1 vermiculite-ash mixture. The critical concentration for increased attack of

alumina-ash mixture has been increased from a ratio of 2/1 to 3/1 or above, and the extent of the maximum attack has been much reduced. With magnesium oxide this phenomenon of an increased attack

at low proportions of oxide addition does not seem to occur and the use of a still atmosphere in the furnace had little effect. This is shown in Table 7.

This accelerated attack by additives in certain proportions is an interesting phenomenon and until further work yields more information it is impossible to say whether it is a chemical or physical effect. An attempt was made to see whether compounds corresponding to the composition of 'mixtures' giving accelerated attack could be prepared by precipitation. Unfortunately zinc vanadates and aluminum vanadates prepared by the action of ammonium metavanadate and salts of the two metals under various conditions were not of this composition and the fact that they were non-corrosive was not particularly helpful.

It is suspected that the catalytic oxidizing ability of V_2O_5 plays some part in the mechanism of corrosion. Its activity in the industrial oxidation of sulfur dioxide can be inhibited by arsenic poisoning of the catalyst. An attempt was made to produce this effect by dosing an ash mixture with small concentrations of antimony trioxide which is chemically

very similar to arsenious oxide. A corrosion test on FDP for 100 hours at 700 degrees C showed that up to 5 percent Sb_2O_3 did not result in any significant reduction in attack (Table 8).

In an engine producing a dry ash, a turbine blade would become coated soon after lighting up the turbine and at the metal surface there would probably exist a layer of ash which would tend to act as a barrier between the blade and further additions; where a dry ash packed between stator blades these conditions would almost certainly prevail. In the case of a molten ash, there would be a continuous diffusion of freshly arriving ash into that already existing on the surface and the question of any falling off in the rate of attack with time is largely academic. In crucible tests, which to a considerable extent imitate the former engine conditions, the results shown in Table 9 were obtained, and these show that the corrosion rate must drop fairly sharply with time.

It is possible, therefore, that a coating of magnesium-oxide-treated ash on the engine parts susceptible to corrosion would exercise a protective action and the fact that 'inhibited' ashes are reduced only in corrosive powers and not made completely non-corrosive may not be as discouraging as it seems at first sight.

TABLE 6—Effect of Still Atmospheres on Additive Corrosion Acceleration

ADDITIVE	Metal	Ratio of Additive to Ash	Milligrams Loss per Sq. Cm. per 100 Hours Air Passed	Milligrams Loss per Sq. Cm. per 100 Hours Air Not Passed
300 Mesh Vermiculite	G18B	0	143.0	106.0
		1	421.0	181.5
		2	40.5	1.9
		2½	8.3	3.9
		3	17.7	1.5
Aluminum Oxide	G18B	0	143.0	106.0
		0.66	100.7	47.8
		1	59.1	38.1
		2	589.0	29.3
		3	49.5	76.1
	Nimonic 80	0	15.3	19.1
		0.66	9.1	8.3
		1	12.7	6.7
		2	68.7	21.9
		3	17.4	27.2

TABLE 7—Reduction of Corrosive Action of Ash Mixture With MgO

Weight Ratio, MgO/Ash	Milligrams Loss per Sq. Cm. per 100 Hours Air Passed			Milligrams Loss per Sq. Cm. per 100 Hours Air Not Passed		
	G18B	FCB(T)	Nimonic 80	G18B	FCB(T)	Nimonic 80
0.25	22.3	7.9	15.3	..	..	..
0.50	0.7	0.5	0.7	..	..	..
0.75	2.7	0.7	0.5	..	..	..
0.80	..	..	..	2.0	0.9	0.7
1.0	0.8	0.7	0.3	..	..	..
1.7	0.9	1.3	0.4	1.5	0.3	0.3
2.0	0.7	0.5	0.5	1.4	0.5	0.3
4.0	2.8	0.6	0.2	0.6	0.6	0.3

TABLE 8—Effect of Sb_2O_3 on Corrosion

Percent Sb_2O_3 in Ash Mixture	Percent Reduction in Weight of Specimen
0	9.5
1.25	10.4
2.5	11.3
5.0	10.9

TABLE 9—Effect of Time on Rate Corrosion—Ash Treated With MgO

Duration of Test, Hours	Percent Loss in Weight After Descaling	
	FCB(T)	Nimonic 80
50	0.051	0.043
100	0.082	0.041
250	0.046	0.044
500	0.057	0.027

Ratio MgO/ash, 1/1; temperature, 700 deg. C.; air passed through furnace; NaH descaling.

TABLE 10—Decomposition Temperatures of Various Sulfates

Sulfate	Decomposition Temperature
$MgSO_4$	890 deg. C (1630 deg. F)
$ZnSO_4$	720 deg. C (1330 deg. F)
$Al_2(SO_4)_3$	590 deg. C (1090 deg. F)

Relation of Laboratory Tests to Engine Conditions

It cannot be too strongly emphasized that all the previously described tests were carried out under laboratory conditions and that care must be adopted in predicting engine behavior. Engine conditions differ from those in the crucible testing by four ways:—

1. The presence of SO_2 , which is liable to react with the basic oxides.
2. The existence of a high temperature zone in the combustion chamber. If, as is desirable, additives are put into the engine together with the fuel then they must pass through this zone.
3. The existence of pressures higher than atmospheric in the engine. If the corrosive action of vanadium compounds on steels is sensitive to pressure then this will probably give higher rates of corrosion than were encountered in the laboratory.
4. Turbine temperatures are usually lower than the 700 degrees C (1290 degrees F) at which the crucible tests were conducted. In the case of the 3500 hp marine gas turbine the turbine inlet temperature is 650 degrees C (1200 degrees F). This use of lower temperatures tends to increase the sulfation of basic additives.

The presence of SO_3 is likely to be the most serious opponent of additive efficiency at lower temperatures. It is capable of reacting with the basic oxides, such

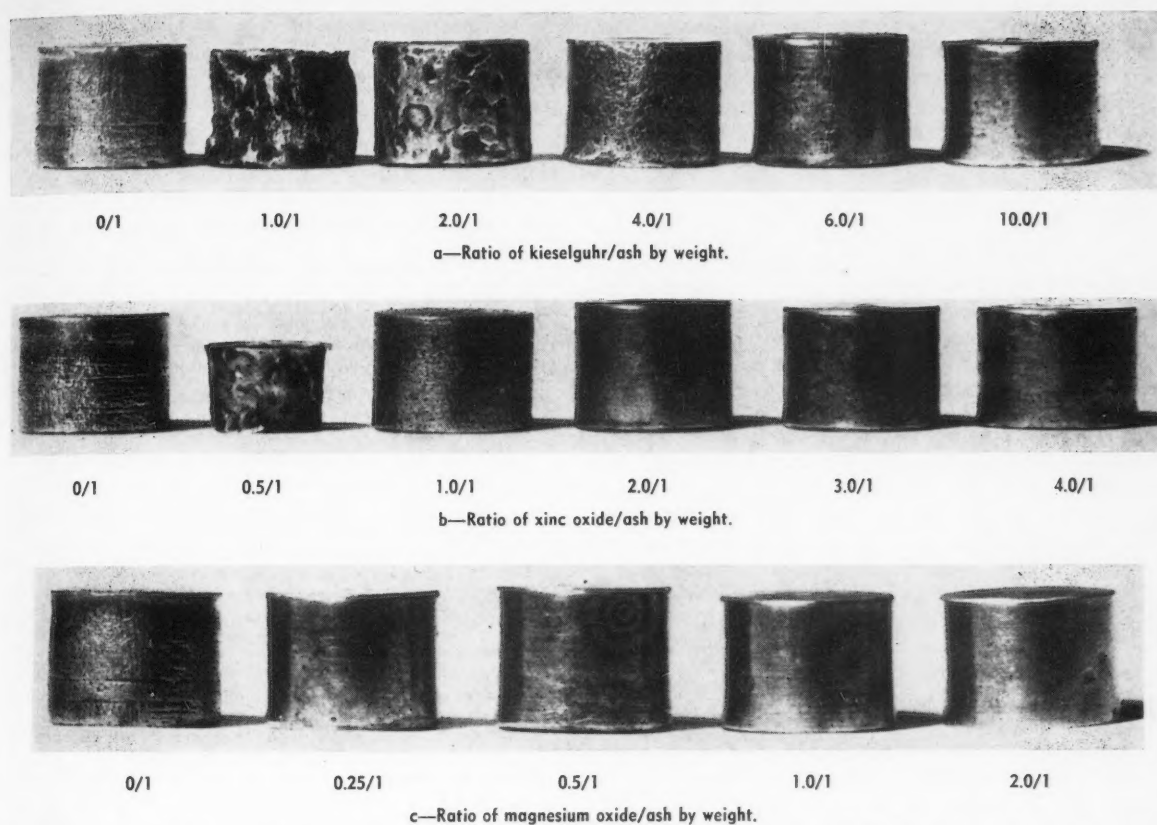


Figure 3—Effect of increasing concentrations of various materials on the corrosion of G18B. Ash mixture: 90 percent V_2O_5 + 10 percent Na_2SO_4 100 hours at 700 degrees C, Sodium hydride descaled.

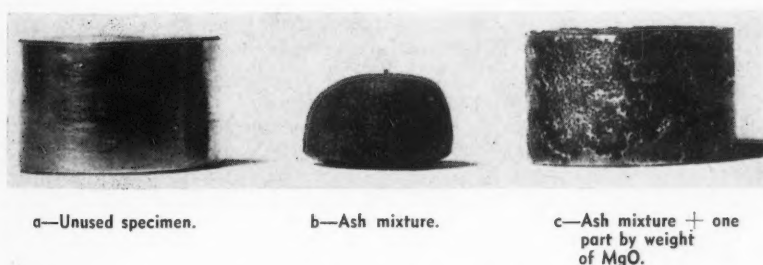


Figure 4—Effect on an equal quantity by weight of MgO on the corrosive action of ash mixture 90 percent V_2O_5 + 10 percent Na_2SO_4 on FCB(T) at high temperature 25 hours at 920 degrees C, sodium hydride descaled.

TABLE 11—Effect of Magnesium Sulfate on Rate of Corrosion

Weight Ratio $MgSO_4$ to Ash	Milligrams Loss per Sq. Cm. per 25 Hours
.....	71.5
1.....	15.2
2.....	12.3
4.....	11.8
6.....	9.8
8.....	14.7
9.....	7.8
10.....	7.2

Material, G.18B; temperature, 700 deg. C.; time 25 hours. Air not passed.

as those of magnesium, zinc and aluminum, so destroying their chemical activity. The sulfate decomposition temperature indicates an upper limit beyond which sulfation cannot occur (Table 10).

That reduction of attack can still take place at temperatures above that of the sulfate decomposition point was shown by an experiment in which an FCB specimen was subjected to the action of molten ash mixtures at a temperature of 920 degrees C. This specimen showed a loss of 72½ percent after descaling, compared with a loss of only 2.1 percent when one part by weight of magnesium oxide was present. The condition of the two specimens is contrasted with an unused one in Figure 4.

It can be seen that in the case of the Pametrada gas turbine, which has an inlet temperature of 1200 degrees F, sulfation is possible for both zinc and magnesium oxides. In the case of calcium oxide, which has received attention from other workers, the sulfate decomposition temperature of 1200 degrees C (2190 degrees F) is so high that its use as an additive is probably not practicable, even although it is capable of forming high melting point inert vanadates.

Some recent laboratory experiments at Pametrada on the thermal stability of magnesium sulfate have shown that in the presence of V_2O_5 it slowly ejects SO_3 at temperatures as low as 650 degrees C. It is believed that this is the reason for the slight cor-

rosion-reducing powers of magnesium sulfate at 700 degrees C shown in Table 11. This behavior is encouraging in indicating that basic type additives (which are the most effective), will be useful to some extent, even at temperatures a little below those which would be expected to give complete sulfation. Rig experiments at temperatures between 650 degrees C and 760 degrees C (1200 degrees F and 1400 degrees F) with magnesium and zinc oxides, using dosages of the order of twice the ash concentration in the oil, have shown very good suppression of attack, even where high-sulfur fuel has been employed. The reduction of attack, however, was invariably less than had been obtained in the laboratory tests. It is interesting to note that some degree of sulfation might actually be beneficial in that it will aid the removal of engine deposits by water washing. With additives not liable to sulfation, for example, silica and alumina (at temperatures above 590 degrees C) there seems to be no reason why the same relative degree of corrosion suppression should not be obtained on an engine as in the laboratory.

If sulfation of basic additives is found to destroy their effectiveness to an intolerable extent, there remains the choice of either suppressing SO_3 formation, or the use of additives which are not liable to its attack.

The suppression of sulfur trioxide formation by inorganic smokes is a very interesting possibility and it is known that its application to corrosion problems is receiving attention from Whittingham (1947 and 1948). Provided that zinc oxide does not show the phenomenon of accelerated attack under engine conditions it will form an ideal additive, both preventing attack by vanadium compounds and reducing sulfur trioxide formation with beneficial results to parts of the engine liable to sulfuric acid attack, for example, the heat exchanger. If, however, zinc oxide is found to be too dangerous to use, then a useful degree of corrosion suppression could perhaps be obtained by the use of an additive which is not liable to sulfation or by joint additions of a basic additive and a finely divided sulfur trioxide suppressor, for example, magnesium oxide and silica.

So far, the discussion of corrosion has been almost entirely limited to that of the turbine and heat exchangers have received little mention. The 3500 shp Pametrada gas turbine heat exchanger is tubed with aluminum bronze and reference has already been made to the attack by ash at a temperature considerably below fusion point.

The promotion of the conversion of basic additives to sulfates by the lower temperatures prevailing in heat exchangers and the lower threshold temperature for vanadium attack of aluminum bronze are additional arguments for suppressing sulfur trioxide formation or using additives which will not sulfate.

There remains finally the question of methods of introducing inorganic corrosion reducers into an engine. This can be done in a variety of ways, such as:

- 1) Oil-soluble compounds producing the additive in the required form on combustion, for example, magnesium naphthenate, ethyl silicate and calcium sulfonate.

- 2) Air-borne powders.
- 3) Powders dispersed in the oil.
- 4) Aqueous solutions of salts producing the additive in the required form on combustion, for example, magnesium and zinc acetates.

The choice of methods will depend on the additive which is employed and on economic considerations. At Pametrada, several of the methods listed above have been used with considerable success in rig experiments.

Conclusions

The authors consider that as a result of their experience of laboratory and rig tests, which latter is still in progress, together with the findings of other workers, the following conclusions may be drawn:—

1. Gas turbine components are liable to be severely attacked by vanadium-bearing ash if the metal temperature is above the melting point of the ash. This attack is not likely to be serious below 650 degrees C. Turbine fouling may occur with a variety of ashes, but is liable to be more severe with low melting point vanadium-bearing ones.
2. None of the commercially available metals or alloys is immune from attack, but a useful degree of resistance can be obtained by the selection of suitable materials.
3. Nickel chromium alloys of the Nimonic type are more resistant than the austenitic steels; those containing molybdenum being the least resistant.
4. Resistance to attack can be increased by the use of protective coatings high in chromium.
5. Copper-base alloys suitable for use in heat exchangers are attacked by vanadium-bearing ashes at temperatures considerably below the melting point of the ash.
6. Dilution of the ash by the addition of magnesium oxide, zinc oxide, aluminum oxide, kieselguhr or vermiculite results in a considerable reduction in the rate of corrosion and should at the same time minimize turbine fouling.
7. Under laboratory conditions all the above additives with the exception of magnesium oxide bring about a marked increase in attack when present in certain critical proportions.
8. The presence of sulfur trioxide in the combustion gases will reduce the effectiveness of magnesium oxide as a corrosion inhibitor. This is unlikely to become significant at temperatures above 700 degrees C but will grow progressively more serious at lower temperatures.
9. The use of finely divided solids which suppress the formation of sulfur trioxide may find application in protecting an additive liable to sulfation and keeping it effective, not only in the turbine but also in the cooler heat exchanger.

Acknowledgments

The authors desire to thank the Research Director of Pametrada Research Station for permission to publish this paper, and wish to express their gratitude for the helpful criticism and advice given by their colleagues throughout the experimental work and in the preparation of this paper.

APPENDIX

References

- A. T. Bowden and J. L. Jefferson, 1949 *Proc. I. Mech. E.*, vol. 160, p. 454, 'The Design and Operation of the Parsons Experimental Gas Turbine.'
- J. B. Bucher, 1950 *Trans. Inst. Eng. and Shipbuilders in Scotland*, Paper 1125, 'Experimental Running of Open and Closed Cycle Gas Turbines.'

- C. T. Evans, Jr. 1950 Am. Soc. Testing Materials Spec. Tech. Pub. 108, 'Oil Ash Corrosion of Materials at Elevated Temperatures.'
- D. F. Hughes and R. G. Voysey. 1949 *Jl. Inst. Fuel*, vol. 22, p. 197, 'Some Considerations Dealing with the Formation of Deposits in Gas Turbine Plant.'
- P. Lloyd and R. P. Probert. 1950 *Proc. I. Mech. E.*, vol. 163, p. 206, 'The Problem of Burning Residual Fuel in Gas Turbines.'
- P. Schlapfer, P. Amgwerd and H. Preis. 1949 Schweizer Archiv für Angewandte Wissenschaft und Technik, *Annales Suisses*, vol. 15, No. 10, p. 291, 'Zur Kenntnis des Angriffs von vanadiumhaltigen Oelaschen auf hitzebeständige Stähle.'
- G. Whittingham. 1947 Paper presented before Eleventh International Congress of Pure and Applied Chemistry, 'Formation of Sulphate Deposits and Acid Condensates During Combustion.' 1948 *Jl. Soc. Chem. Industry*, vol. 67, p. 411, 'The Influence of Silica Smokes on the Dewpoint of Combustion Gases Containing Sulphur Oxides.'

Communications

Mr. A. Lewis (Chester) wrote that in addition to the general accelerated oxidation observed by the authors there would be in practice an additional corrosive attack following upon reduction of sulfate deposits immediately adjacent to the metal surface. The second attack took the form of intercrystalline sulfide formation and its existence had been confirmed by Skinner and Kozlik (1950)*, the high nickel alloys particularly being more susceptible to attack.

The ultimate significance of any form of attack upon, for example, turbine blades would be the effects upon operational life of the blades and reduction in that could result from either of the two forms of attack described above. Accelerated oxidation would result in a loss of actual visible cross section of metal, while the intercrystalline attack could give no external indication of attack while still giving an appreciable reduction in effective cross section. While the method of testing used by the authors and others, in which specimens of metal were immersed in mixtures of metallic compounds or fuel ash at different temperatures near or above the melting point of the mixture, would give an indication of the relative resistance of different materials to oxidation by ash of the type chosen, it would not take into account possibility of the intercrystalline sulfide attack. That defect could be overcome only by resorting to combustion testing, where the specimens were actually exposed to the combustion products of the same type of fuel as would be used in practice and even then only if a more practical method of assessment of the deterioration in the metal were used. Such a method had been developed at the Thornton Research Center and had been used extensively there for examination of the performance of materials.

The method used involved exposing the materials in the form of tensile test pieces at 800 degrees C to the combustion products of a 2000-second residual fuel oil. After 100 hours' exposure the test pieces were broken on a tensometer and from a direct comparison of the ultimate tensile strength with that of a similar test piece of the same material which had

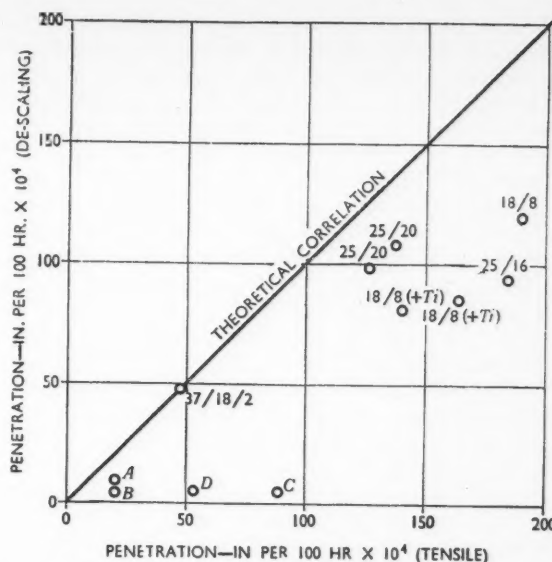


Figure 5—Comparison of corrosion rates deduced by tensile and weight loss methods. A—78 percent: 19 percent Cr, 0.6 percent Si. B—80 percent: 14 percent Cr, 0.6 percent Si. C—75 percent: 20 percent Cr, 0.6 percent Si, 2 percent Ti. D—56 percent: 20 percent Cr, 19 percent Co.

been exposed to the products of combustion of an ash-free fuel for the same length of time and at the same temperature an estimate could be made of the effective cross section of the test piece. The reduction in cross section was then expressed as the equivalent thickness of metal lost.

Machined rectangular specimens of the different alloys had also been exposed at Thornton simultaneously with the tensile test pieces, and their corrosion had been assessed from the weight loss of the specimens after descaling electrolytically in a molten mixture of 60 percent Na_2CO_3 and 40 percent NaOH . Typical results for one fuel were given in Figure 5, where the equivalent metal thickness loss was plotted for the two methods of assessment for a range of materials. It would be noted that, apart from the general departure from the 45 degree line, there was a much greater variance between the 'tensile' results and the 'de-scaled' results for the high-nickel type of alloy than for the other types. In view of the greater susceptibility to intercrystalline penetration of those particular alloys, it was not surprising to find that the effective loss in section was greater when deduced from tensile test results than when it was obtained by the more straightforward de-scaling technique.

Protective Coatings. The authors' findings on the lack of protection by electrodeposited coatings confirmed the results obtained at Thornton with a wide range of coating materials. The coatings disintegrated either as a result of oxidation of the basis alloy which proceeded as a result of the porosity of the coating, or else as a result of differential expansion between the coating and basis metal. The application of the coatings to a stainless steel showed a little improvement but no electrodeposited coating was sufficiently promising to warrant further development. That statement also applied to materials which

* Skinner, E. N., and Kozlik, R. A. 1950 ASME Petroleum Mechanical Engineers' Conference (September).

would normally have a very great resistance to oxidation, for example, platinum. The promise shown by chromizing in Evans' tests was supported by results of tests with a chromized mild steel tube, although it is probable that subsequent inward diffusion of the chromized layer might detract from long-term improvements by that method, unless the basis metal itself possessed some degree of inherent oxidation resistance. Chromizing of high nickel alloys would therefore suggest itself as one very probable method of producing extreme resistance to accelerated oxidation.

Low-temperature Ash Corrosion. The attack at 500 degrees C by mixtures of V_2O_5 and Na_2SO_4 investigated by the authors was interesting, particularly as the supporting tests carried out on the BNFMR materials indicated a more widespread attack with unfused ash than with prefused ash. That was quite consistent with the attack being caused by the products of reaction of V_2O_5 and Na_2SO_4 and it would be extremely interesting to see such tests carried out in a more comprehensive manner with different proportions of Na_2SO_4 , for, after all, in practice a fuel ash would be likely to vary widely in composition from batch to batch. The vapor pressure of V_2O_5 at 500 degrees C was extremely small but if the attack was due to the presence of V_2O_5 vapor it would have been far more representative of practice to carry out tests at least in a flowing gas stream containing the inevitable SO_2 and SO_3 , if not in true combustion flue gases.

Mr. H. Lewis, B.Sc. (Birmingham), wrote that there would be general agreement with most of the opinions expressed by the authors on the relative merits of the materials tested against attack by mixtures of vanadium pentoxide and sodium sulfate and it was rightly emphasized that even the least susceptible alloys were by no means immune from attack.

A number of investigators had been driven by that conclusion to a consideration of treatment of fuel oils by additives, either before or during combustion as a possible means of avoiding or mitigating the attack. There was every indication as in the present paper that such methods could achieve at least a measure of success.

Difficulties were likely to arise, however, from the greatly increased amounts of ash which such additives produced. On the one hand that might lead to increased fouling of the turbine blading if the ash remained adhesive. On the other hand a less adhesive ash might give rise to severe erosive effects, depending on the amount of ash and the nature of the ash particles.

A balanced solution to the problems of corrosion, erosion and fouling by ash deposition was by no means impossible but those concomitant problems added point to the authors' warning that laboratory corrosion tests could not be a precise guide to engine behavior.

The authors had wisely avoided too much useless speculation on the chemical or physical modifications of the ash which might have caused the observed

effects of the various additives, but had yielded to the temptation of assuming what, one felt, might be a rather over-simplified role for SO_3 in oil-ash corrosion.

In addition to neutralizing the effect of basic corrosion inhibitors as the authors had suggested, SO_3 was capable of attacking heat-resisting alloys directly under certain conditions and a damaging attack could occur resulting in the formation of chromium sulfide which led in turn to rapid oxidation. Contamination by sulfides had actually been observed in samples of chromium-bearing heat-resisting alloys exposed to the products of combustion of residual fuel-oil and of other sulfur-containing fuels.

Sulfides were not normally observed in samples attacked by synthetic mixtures of vanadium pentoxide and sodium sulfate in laboratory tests of the type carried out by the authors, but it was clear that sulfur had a powerful destructive potential which might play a considerable part in the corrosion by vanadium-containing ashes. If, as the authors had suggested certain additives could combine with SO_3 , then far from being undesirable, that combination might be one reason for the effectiveness of those additives. It would be unwise to rule out calcium oxide as an additive in the presence of SO_3 merely because of the high temperature of decomposition of calcium sulfate.

Mr. J. J. Macfarlane and Dr. N. Stephenson (Whetstone, Leicester) wrote that they and their colleagues had investigated in the laboratory the effect of the Na_2O/V_2O_5 ratio of synthetic ashes on the corrosion of Nimonic 80A and FCB(T) in the temperature range 650-800 degrees C. The ashes had been prepared by mixing intimately sodium orthovanadate with vanadium pentoxide and roasting at 800 degrees C. Known weights of ash had been coated over small specimens. After exposure for 100 hours' duration at test temperature the specimens had been de-scaled to determine alloy loss due to corrosion. For specimens exposed to still-air atmospheres, maximum attack had been caused by Na_2O/V_2O_5 molecular ratios of 1/4 (cf. the authors' Na_2SO_4/V_2O_5 molecular ratio 1/7). Under those conditions FCB(T) had been more severely corroded than Nimonic 80A. When the tests had been repeated using moving air atmospheres containing 0.1 percent SO_2 and 0.01 percent SO_3 by volume the corrosion associated with Na_2O/V_2O_5 molecular ratios of approximately 1/4 had been diminished. With Nimonic 80A at temperatures below 750 degrees C the maxima had been nearly eliminated and corrosion had been dependent almost completely on the weight of V_2O_5 contained by the ash and of course on the test temperature. That feature was consistent with results obtained from combustion rig tests in which Nimonic 80A blades had been subjected to continuous deposition of natural fuel ash. There, the rate of oxidation had been related directly to blade temperature and the deposition rate of V_2O_5 , and apparently had been independent of ash composition. The relationship was valid for blade temperatures in the range 600-750 degrees C and provided the deposition rate of V_2O_5 did not exceed

approximately 0.2 milligram per sq. cm. per hour.

Although formation of the sodium vanadyl vanadates was known to occur at $\text{Na}_2\text{O}/\text{V}_2\text{O}_5$ molecular ratios of approximately 1/4, equilibrium data for the $\text{Na}_2\text{O}-\text{V}_2\text{O}_5-\text{SO}_3$ system were not available. It was possible that low SO_3 partial pressures over mixtures of Na_2SO_4 and 10 percent V_2O_5 could lead to loss of SO_3 and O_2 and to the formation of the highly corrosive vanadyl vanadates. That might account for the variation in the authors' oxidation values between the still- and moving-air conditions unless, of course, they had roasted their synthetic ash before commencing the tests. However, when oxidation was rapid the rate of attack was frequently dependent on air-flow rate up to a critical value.

They themselves, employing 'coating' tests of the type outlined above, had examined the effect of $\text{MgO}/\text{V}_2\text{O}_5$ and $\text{ZnO}/\text{V}_2\text{O}_5$ ratio on the oxidation at 700 degrees C of Nimonic 80A, FCB(T) and G18B using moving air atmospheres containing 0.1 percent SO_2 and 0.01 percent SO_3 by volume. Synthetic ashes corresponding to the formulae V_2O_5 , $\text{Na}_2\text{O} \cdot 0.7\text{V}_2\text{O}_5$, $\text{Na}_2\text{O} \cdot 0.4\text{V}_2\text{O}_5$, and $\text{Na}_2\text{SO}_4 \cdot 7\text{V}_2\text{O}_5$, respectively, had been investigated. In all instances attack by the fuel ash had been suppressed at high $\text{ZnO}/\text{V}_2\text{O}_5$ or $\text{MgO}/\text{V}_2\text{O}_5$ ratios. The increase in corrosion which the authors had reported for low or intermediate $\text{ZnO}/\text{V}_2\text{O}_5$ ratios had not occurred. It was possible that the accelerating effect was related to the loss of sulfur trioxide and that the additives either promoted the formation or the action of the vanadyl vanadates. With increase in SO_3 partial pressure, as might have occurred with the authors' specimens exposed to still air, increased additive concentrations had been required to produce the maximum effect.

They themselves had found that, during combustion rig tests, zinc-inhibitors had effectively diminished the SO_3 concentration in the gas stream. In the blade temperature range 600-800 degrees C very little sulfation of the deposits had occurred. Although low SO_3 concentrations associated with high $\text{ZnO}/\text{V}_2\text{O}_5$ ratios favoured vanadate formation in the equilibrium additive sulfate \rightleftharpoons vanadate, low SO_3 concentrations associated with low $\text{ZnO}/\text{V}_2\text{O}_5$ ratios might give rise to the undesirable accelerating effect.

Incomplete knowledge of the reaction kinetics masked the relationships between laboratory and combustion rig or engine test results. The oxidation rates of Nimonic 80A subjected to regular, frequent, intermittent applications of fuel ash under laboratory conditions, could be related directly to the corrosion of the same alloy occurring in combustion rig experiments (within the ranges of blade temperature and V_2O_5 deposition rate mentioned above). When rates of continuous ash deposition were increased above that limit, the corrosion rate reached a maximum and then decreased. Similarly, it was fairly well known that when a specimen was half-immersed in molten ash, maximum metal penetration was located usually at the intersection with the ash-air interface. With low and medium ash deposition rates the oxidation rate could be governed by diffusion of metal or oxygen through the corrosion products, whereas with

high ash deposition rates diffusion through the ash deposit might well be the rate-controlling process. Although a parallel might exist between 'total immersion' types of test and a condition of continuous heavy ash deposition, the turbine choking associated with that rarely could be tolerated.

'Immersion' tests using ashes of high sodium content at temperatures exceeding 750 degrees C sometimes gave rise to a localized catastrophic attack similar to 'green-rot'—particularly on nickel-chromium-based alloys. There was a danger that under those conditions unfired synthetic ashes of only moderate sodium sulfate content might also initiate that type of corrosion.

From those aspects 'immersion' experiments might be the least realistic of the available laboratory techniques.

The laboratory 'coating' test results had not yet been related directly to practical conditions of low-ash deposition rates. However, for Nimonic 80A the reaction kinetics had been found to have certain features in common and the quantitative chemical effects of fuel additives had been similar.

The authors had found that additives were less effective in combustion rig tests than in laboratory experiments. The basis on which the comparison had been made was not clear. The observed corrosion should be related to the ratio of additive/ash in the blade deposits rather than to the corresponding ratio in the fuel.

The simple laboratory corrosion techniques and combustion rig tests had in common the disadvantage that behavior of alloys subjected to static and fluctuating stresses could not be studied.

Mr. R. L. Samuel (London) and Dr. T. P. Hoar (Cambridge) wrote that although the authors followed Sykes and Shirley (1951)¹ in believing that the production of basic oxides, especially magnesia, in ash-containing vanadium pentoxide offered the best present possibility of alleviating its corrosive action, it was interesting that they were not without hope that effective surface treatments of the alloys concerned might be found. The authors' experiments with electrodeposited chromium coatings, which had failed not by corrosion but by thermal cracking, coupled with those of Evans (1951)² with diffused chromized coatings, had led them to the view that chromizing might find 'limited application' in gas turbines.

Evans (1951) had found that chromizing improved the resistance of mild steel and especially of 14-18 percent chromium ferritic stainless steel (Type 430) to corrosion by oil ash. He had also tested coatings formed by the simultaneous diffusion of chromium, aluminum and silicon and found them less effective than plain chromizing, although they gave some protection to 14-18 percent chromium steel and also to austenitic and certain 'super-alloy' materials. Evans had apparently made no tests of plain chromizing on those two latter classes of material; Sykes and Shirley (1951) in some very limited tests had found only a moderate improvement conferred by plain

chromizing upon a complex chromium-nickel-cobalt-molybdenum-copper-titanium steel.

Since it was now possible to chromize austenitic stainless steels, steels of the G18B type, alloys of the Nimonic series and other complex heat-resisting materials with the formation of high-chromium surface layers resistant to thermal shock (Samuel and Lockington 1953)³, there appeared to be a case for the systematic examination of such chromized materials from the standpoint of oil-ash corrosion. The relatively high temperatures (1000–1050 degrees C) needed for chromizing had no disadvantages for many of those basic materials—the austenitic stainless steels, for example, were in any case regularly heat-treated at 1050 degrees C and upwards. Moreover, the production of surfaces very high in chromium by the use of chromizing compounds containing metallic chromium, rather than the cheaper ferrochrome used for the chromizing of mild steel should not be out of the question for those relatively valuable alloys. Finally, modified vaporphase deposition and diffusion processes leading to complex coatings containing several metals were being worked out and improved and it was not impossible that some of them might be found to have value as surface treatments for gas turbine alloys against oil ash.

Dr. C. Sykes (Member), FRS, and **Mr. H. T. Shirley** (Sheffield) wrote that the authors' account of work on the vanadium problem by Pametrada Research Station was of great interest. In most directions their own work had led to very similar conclusions but there were aspects on which some further consideration might be useful.

The possibility of greatly reducing the vanadium trouble by addition of inhibitors was particularly attractive. In the absence of the sulfation complication, there was no doubt that very effective inhibition could be achieved by additions of basic oxides such as those of calcium or magnesium. The lower stability of magnesium sulfate gave it an advantage over calcium and it was the addition they themselves considered most promising for practical development at the time of the 1951 Symposium (Sykes and Shirley 1951).⁴

Subsequent laboratory and rig tests had shown the importance of the sulfation factor, stressing the importance of low sulfate stability in additions of that type. Zinc oxide was particularly attractive and although they would not agree that no sulfation could occur above the 'decomposition' temperatures of Table 10, the difference between the oxides CaO, MgO and ZnO was clearly seen in laboratory tests with mixtures of V_2O_5 and basic oxide heated in sulfur-bearing products of combustion.

To ensure prior combination of the base with V_2O_5 they had used only half the amount of basic oxide corresponding to the formula $(MO)_2V_2O_5$. The mixtures had been ground, preheated in air at 1000 degrees C for 5 minutes, reground and exposed for 6 hours to the products of combustion of a 6/1 mixture of air and town gas, with precombustion addition of H_2S equivalent to 0.5 percent SO_2 in the products

of combustion. Analysis for percentage of SO_3 in the oxide mixtures then gave the following results:

Basic oxide .	700 deg. C	800 deg. C
CaO . . .	2.47	1.29
MgO . . .	0.98	0.09
ZnO . . .	0.12	0.37

However, against the lower sulfation of the zinc oxide must be set a rather lower inhibitive efficiency. That was shown, for example, by tests for 20 hours at 750 degrees C in their standard synthetic ash mixture (26.5 percent V_2O_5), with addition of the inhibitive oxide to three times the amount corresponding to the $(MO)_2V_2O_5$ formula, preheating at 1000 degrees C before the actual test. The tests had been made with 337 steel (2) of the 1951 paper (where details of the ash and test procedure would be found on p. 164), and the results were as follows:

Basic oxide addition	Loss of weight, milligrams per sq. cm.
None	101.3
Al_2O_3	156.7
ZrO_2	228.0
CuO	3.8
ZnO	4.5
MgO	2.1
CaO	1.0

Zirconium oxide had been included because of the considerable instability of the corresponding sulfate, but neither that oxide nor Al_2O_3 showed any indication of inhibitive properties. Copper oxide inhibited attack but caused fusion of the ash mixture during the preheating at 1000 degrees C, suggesting a probable adverse effect on fouling.

Such tests gave valuable indications but the position was complicated and they must obviously be supplemented by extensive rig tests before ultimate practical conclusions were drawn in any particular case. Full consideration of the fouling aspect must be included in any such appraisal.

The authors attributed accelerated attack on aluminum bronze above the ash level, at 500 degrees C, to vapor-phase attack by the V_2O_5 . Tests which they themselves had carried out at the considerably higher temperature of 750 degrees C (*loc. cit.* p. 366) had indicated that very little volatilization of V_2O_5 occurred at such temperatures and that the accelerated attack resulted from creepage. The distinction had obvious importance in the proper interpretation of results and estimation of probable severity of attack under varying conditions of service.

Finally, they asked the authors whether they were satisfied that the FCB(T) of Figure 1a, d, and e, had indeed suffered intergranular attack on test. Their own experience had been that after very severe attack in the presence of V_2O_5 , an intergranular phase appeared which, under some etching conditions gave an appearance similar to the micrographs of Figure 1. With appropriate etching and at higher magnifica-

tion the intergranular constituent was clearly seen and did not appear to induce selective oxidation. Moreover, it did not have an obvious embrittling action; quite severe cold deformation producing no opening of the affected surface. The micrograph of Figure 6 showed the edge of a specimen cold deformed after 65 hours at 830 degrees C in a mixture of 90 percent V_2O_5 and 10 percent Na_2SO_4 . That specimen had suffered very heavy attack, losing 1382 milligrams per sq. cm. during the test.

Authors' Reply

Mr. S. H. Frederick and Mr. T. F. Eden wrote in reply to the communications that the reported sulfide penetration attendant on vanadium corrosion presented some puzzling features. Not surprisingly it was said to be greatly increased by reducing atmospheres but some workers made no mention of that. It was well known that on metal specimens partly immersed in molten mixtures of V_2O_5 and Na_2SO_4 the maximum attack was found at the ash-air interface where air had free access. High nickel alloys were also said to be more liable to sulfide penetration yet the Nimonic alloys were amongst the most ash-corrosion-resistant of the heat-resisting materials.

Whatever the significance and the conditions required for sulfide attack they agreed that the test method adopted, while indicating the relative resistance of different materials, did not take it into account. They considered, however, that that could only be done satisfactorily by means of micro-examination. The assessment of the metal loss by reference to the reduction in the ultimate tensile strength of a tensile test-piece exposed to fuel ash was, in their opinion, liable to be very misleading. The presence of inter-crystalline sulfide penetration would undoubtedly reduce the ultimate tensile strength to a greater extent than a more general metal loss but so would be the effect of surface roughening and that might well be responsible for the greater variance between tensile results reported by Mr. Lewis.

Following the preliminary work which formed the subject of the paper, they had had the opportunity of examining the effect of additives under combustion rig and actual engine conditions. The results tended to support Mr. Lewis's suggestion that additives might lead to increased blade fouling under certain conditions and indeed it had become necessary to concentrate more on the fouling problem than on the corrosion aspect of ash deposition.

It could not be denied that the role of SO_3 in the corrosion of heat-resisting steels was complex but the suggestion that sulfation of additives was beneficial and might be one reason for their success could be accepted only with difficulty. In the laboratory, additives had been tested in the absence of a sulfur oxide-bearing atmosphere and had given very good suppression of corrosion. Under rig conditions, where sulfation could occur, the performance of the basic addition compounds was poorer than in the laboratory. The deterioration in performance, however, did not seem to be directly related to the ex-

tent of sulfation, as on occasions some 90 percent of the magnesium oxide in blade deposits had been found to exist as sulfate without extinction of anti-corrosion properties.

The effect of sodium sulfate concentration on V_2O_5 corrosion had recently been re-studied by use of a different technique, and it had been found to agree with the results quoted by Mr. Mcfarlane and Dr. Stephenson that the maximum attack on Nimonic 80 in still-air atmospheres occurred at a sodium sulfate concentration approximating to a molecular ratio of Na_2SO_4/V_2O_5 of 1/4. With G18B, however, the maximum attack was reached at a molecular ratio of 1/3.

Rig tests at Pametrada had shown that zinc oxide was inferior to magnesium oxide from the standpoint of corrosion suppression at about 650 degrees C which approximated to the turbine inlet temperature of the 3500 hp experimental engine. The reference to SO_3 suppression brought about by that oxide was very interesting and indicated that, in spite of its comparatively poor anti-corrosion properties and the possibility of accelerated attack at low dosages, it was worthwhile investigating.

They agreed wholeheartedly that laboratory corrosion techniques and combustion rig tests, while undoubtedly valuable, did not sufficiently simulate actual engine conditions. Apart from the question of the effect of stresses on alloy corrosion, it was doubtful whether the fouling problem could be solved without frequent recourse to engine testing.

Although a number of workers had reported the beneficial effects obtained by chromizing, they themselves did not consider that the use of coatings offered a complete solution. Irrespective of the reduction in corrosion obtained, there would still remain the question of fouling and as far as chromizing was concerned it would be difficult to avoid distortion of components such as turbine blades at the high temperatures necessary to obtain a reasonable rate of diffusion. In addition the treatment of large components such as flame tubes and hot gas ducting would be very costly.

In a large number of tests in which specimens had been only partially immersed in mixtures of molten ash they had observed creepage. With the tests on aluminum bronze, however, the ash had remained completely dry at 500 degrees C and under such conditions creepage could hardly be expected to occur.

They were very interested to learn that Dr. Sykes and Mr. Shirley had observed an inter-crystalline phase appearing in FCB(T) after severe attack in the presence of V_2O_5 . It was surprising that no embrittling effect had been found, and they would like to know whether such a phase would be expected to affect the creep and fatigue properties of the steel.

References

1. Sykes, C., and Shirley, H. T. 1951 Iron and Steel Inst. Special Report No. 43, p. 153.
2. Evans, C. T., Jr. 1951 Am. Soc. Testing Materials, Symposium on Corrosion of Materials at Elevated Temperature, p. 59.
3. Samuel, R. L., and Lockington, N. A. 1953 Trans. Inst. Metal Finishing (in the press); and unpublished work.
4. Sykes C., and Shirley, H. T. 1951 Iron and Steel Inst. Special Report No. 43, p. 166. "Scaling of Heat Resisting Steels—Influence of Combustible Sulphur and Oil Fuel Ash Constituents."

Notes on a System For Rating Pitting Corrosion*

By RUSSELL W. HENKE

PITTING corrosion may be defined as the highly localized attack of a material by a corrosive medium, characterized by degraded areas whose depths are relatively great when compared to the cross sectional area of the void.

A requirement has been evidenced for a method of presenting pitting corrosion data in a standard terminology so that it can be universally interpreted in a consistent manner. The familiar "ipy" and "mdd" system presently used with success for cases of uniform corrosion, breaks down with respect to pitting corrosion. This is obvious because failure can occur due to pitting upon perforation of the material by only one pit, while the actual "ipy" or "mdd" could be negligible.

The complexity of a system undergoing pitting corrosion renders impractical attempts to rate this type of attack in terms of the causes of pitting, nature of corrosion products and similar factors related to the electrochemical phenomena involved in the system. Indeed, insofar as the damage done by pitting corrosion is concerned only the physical characteristics of the pit are of importance.

Therefore, in an attempt to reduce all possible examples of pitting corrosion to a standard scale of comparison, only the physical characteristics of the pits will be utilized.

Universal Criteria Listed

In an analysis of corrosion pits, the following characteristics are believed to meet the criteria of universality and relevance to a standard rating system:

1. Depth of Pit
 - a. The depth of pit to be expressed as a percentage of the material thickness rather than a finite dimension.
2. Equivalent Diameter of Pit
 - a. For pits of a general circular form this number has finite significance.
 - b. For irregular pits, this number would express the diameter of an equivalent circular section whose area would be equal to that of the actual pit.
3. Area of Pits expressed as a percentage of total surface area.
4. Nature of Pit Walls
 - a. Some pitting corrosion results in pits with almost vertical walls.
 - b. Some other types of pits show walls with a gradual slope.
5. Time Element
 - a. The time in which the pitting occurred reduced to a standard interval.

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Abstract

A system is proposed for describing corrosion pits in a metal surface by a combination of agglutinated numbers and letters coded to a schedule rating the five principal characteristics of pitting corrosion. The system would facilitate transmission of pitting data by providing a 10-digit number covering their depth, equivalent diameter (including those of irregular shape), area (expressed as a percentage of total surface), nature of pit walls and time (reduced to a standard interval).

Pit depth is expressed as a percentage of material thickness rather than a finite dimension, walls would be rated vertical or gradual in comparison with a 45 degree angle and time would be in penetration per year. Area of pits as percentage of total area would be determined by placing over the pitted surface a transparent grid and comparing the area visually with a conventional standard delineating 10 stages of severity.

Suggestions and recommendations for improvement of the system and submission of specimens of pitted material are solicited by the author.

The preceding characteristics were considered to be representative of the information which would be required to pass judgment on the applicability of a material in a given corrosive environment.

Depth of Pits

The depth of pits, for example, is of prime importance in pipe lines and pressure vessel work, for it gives an index to the anticipated rate of perforation of the materials. It was felt that expressing the depth as a percentage of the material thickness was far more satisfactory than giving an actual measurement for the obvious reason that a depth of pit in a thin wall vessel would be far more serious than the same depth in a thick wall vessel or pipe. The expression in percent alluded to would serve to point up the relative severity of the pitting attack.

Mean Diameter of Pits

The mean diameter of the pit, suggested as Point 2 of the system, was included to provide a means of comparing the size of pits formed under varying con-

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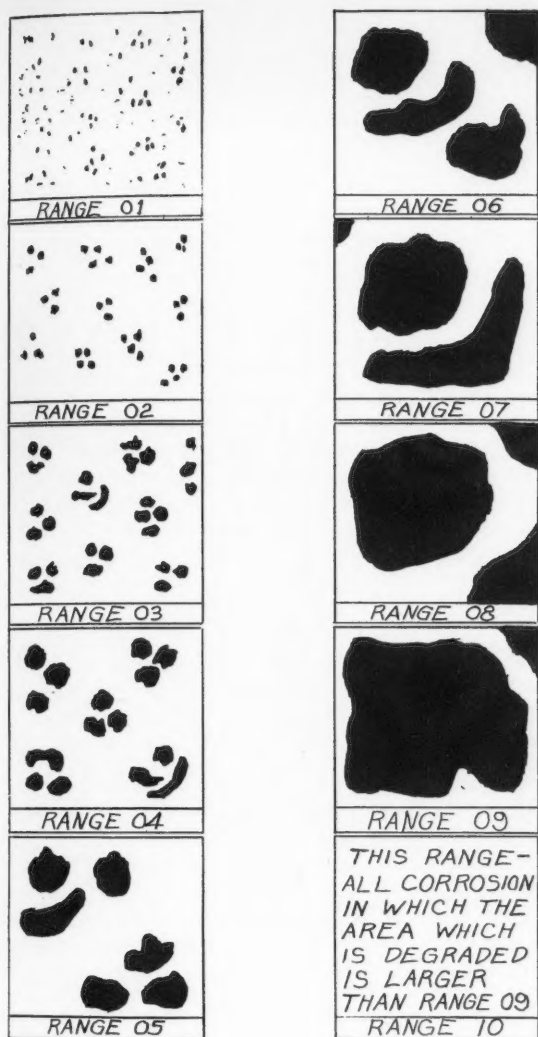


Figure 1—Standard equivalent pit diameter ranges for Henke corrosion pit rating system.

ditions. For pits of equal depths, the mean diameter of the pit would serve as an indication of the relative severity of attack. The mean diameter factor is really intended as an indicator of the area affected by a single pit. This might be of prime importance in pitting of parts bearing against one another for example.

Percent of Area Pitted

While the mean diameter factor is an attempt to rate the deleterious effect of a single pit, areawise, the third factor, "Area of Pits expressed as a percentage of the total area," is intended to rate the effect of the total area deteriorated against the total surface area of the material in the attacked zone. It is, in other words, the ratio of all the "Pit mean diameter areas" to the total surface area available, expressed as a percent. This factor would give a measure of the dispersion of the pitting attack over the surface of the material.

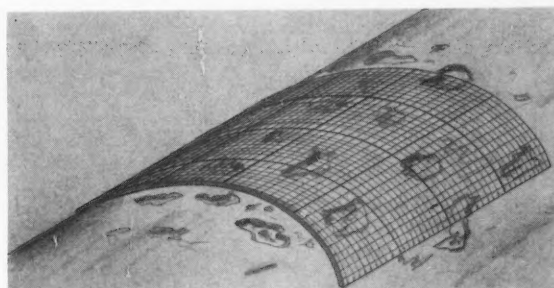
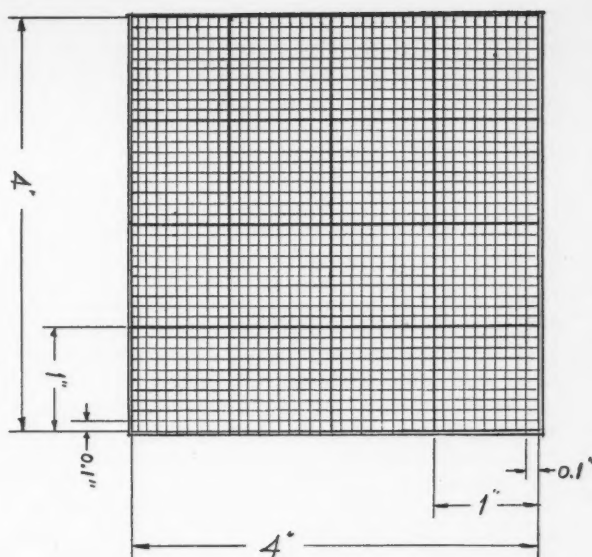


Figure 2—(Top) Standard grid for use in determining percentage of surface area pitted. (Bottom) Showing application to cylindrical surface.

Nature of Pit Walls

The factor for indicating the nature of the pit walls is included because in some applications, sharp pits would act as stress concentration points and might be the focal point for fatigue failure. Conversely, gradually sloped walls on pits would not have nearly the stress raising characteristics of the sharp pits. This slope-walled pitting has been described by some authorities as "cratering."

Element of Time

The final factor listed for the rating system is the time element. Obviously, two pits of the same characteristics, one formed in three months and the other in three years, do not represent in the same degree the critical nature of the attack. Therefore, the pitting corrosion observed must be reduced to some standard time interval in order that a comparison may be drawn between examples to be rated. This can be a difficult task since the rate of corrosion need not be expected to be uniform over the elapsed corrosion time.

With the foregoing discussion in mind, the system proposed to organize these rating factors into a standard rating symbol for pitting corrosion can be examined.

The author decided, as a first attempt, to set up ten standard ranges for equivalent pit diameter, in a manner analogous to the SAE grain size classification charts for steel with which all are familiar. These ten standards are illustrated in Figure 1.

Corrosion falling outside the maximum (No. 10) rating is to be considered as localized general corrosion rather than as true pitting by virtue of the large area involved in comparison to the depth of penetration. This type of corrosion may be rated by using ipy or mdd ratings.

It is thought that the equivalent diameter rating number could be applied to actual pitting corrosion cases by the same methods used in applying grain size classification numbers, i.e., observation and comparison. Perhaps it would facilitate a classification to have rating charts worked up on transparent templates which could be laid over the specimen and the rating obtained by direct comparison.

The depth of pit expressed as a percentage of wall thickness would be obtained by direct measurement and simple calculation.

Standard Grid Is Proposed

In order to express the area corroded out by pitting as a percentage of the total surface in the attacked area, a standard grid is proposed, see Figure 2. This grid is to be ruled on transparent, flexible plastic sheet so that it may be laid over the corroded area and the pitted area estimated from the squares on the grid. When the pit area has been estimated, the total area of the grid being known, the percentage of total surface area corroded can be simply calculated.

The nature of the pit walls can be observed and it is proposed that "steep walled pits" be defined as those whose walls slope at an angle greater than 45 degrees with the horizontal and "gradual sloped walls" be those making an angle of less than 45 degrees with the horizontal.

In the rating system proposed by the author, the code for steep walled pits would be "S" and for gradual sloped walls for be "G".

The time element is perhaps as important a factor in pitting corrosion as any other. It is the rate of pitting, or penetration, which is critical. For the purposes of the rating system, the time element will be expressed as a penetration equal to a percentage of the material thickness per year. This is in contrast to the first factor which merely expresses total penetration regardless of time.

Thus, the total penetration of a pitting type corrosion might be 30 percent of the wall thickness, but the time-integrated penetration rate would be 10 percent per year if the pitting occurred over a 3-year period.

The nomenclature for the author's rating system would be set up as follows:

AAA B CC DD EE

Where

- AAA—gives the total penetration of the pit expressed as a percentage of material thickness (up to 100 percent, i. e. perforation)
- B—Pit Wall Characteristics
 - S—Steep Walled
 - G—Gradual Slope wall
- CC—Area of pits expressed as a percentage of total surface area corroded.
- DD—Time integrated rate of penetration expressed as percentage of wall or material thickness per year.
- EE—Equivalent diameter of pit rating number (from chart of standard pit size ranges, Figure 1).

From this nomenclature, it could be discerned that a specimen (which had been in service four years) labeled, say 84S152101 would be one showing 84 percent penetration, with pits generally sharp, steep walled and covering about 15 percent of the attacked area; the average rate of penetration would have been 21 percent a year of the total wall thickness; ($84/4 = 21$), and would be in range size 02 of the equivalent diameter rating chart.

This information would be accurately interpreted anywhere it was transmitted and would replace a large amount of detail now required to convey approximately the same information in written description. As a matter of fact, the single code number transmits the same information which required the whole previous paragraph to convey in writing. There could be no mistake as to its content or intent.

Applications of a standard rating system for pitting corrosion should be obvious. That the need exists for reducing such data to standard terms is almost universally accepted. The author hopes that the system proposed in this discussion will prove suitable to fit the requirements of the problem and will, at least be instrumental in provoking the demand for the establishment of such a standard rating system for pitting type corrosion.

Author's Note

This paper represents the author's initial attempt at formalizing and setting down some of his concepts of a standard rating system for pitting corrosion.

It is hoped that this presentation will stimulate the discussion and controversy so necessary to the refining of an idea such as this to its highest possible state. Only after such refinement can this proposal be successfully applied to actual conditions in the field.

Perhaps some of the factors included in the rating number or symbol are considered to be irrelevant by one school of thought, while others may feel that something of significance has been omitted.

The author sincerely solicits readers' comments on the idea and would also appreciate reader participation to the extent of submitting samples (reasonable size) of pitting corrosion together with case histories of the specimen, in order that more detailed work on a wide variety of actual cases may be carried out.

Cathodic Protection of Open Box Coolers*

By J. P. H. ZUTPHEN*

Abstract

Application of cathodic protection to exterior surfaces of tubes used to cool ammonia gas at pressures of 280 to 300 atmospheres is described. Because of space and other considerations, graphite anodes and impregnated graphite anodes were employed.

Heavy deposits of salts occurred initially on tube areas nearest anodes but little on surfaces farther away because of close spacing of anodes and tubes. When current was reduced, deposits diminished and heat transfer rates improved. A seasonal variation in the salt content of the cooling water resulted in an increase in resistance of the water and a corresponding decrease in the polarization of the tubes. This allowed corrosion of tubes farthest from anodes which was stopped when the anodes were relocated outward from tube surfaces to give better current distribution and output of selenium rectifiers was increased to return potential to design —850 millivolts.

Success of initial experiments with the coolers resulted in application of cathodic protection to new and larger coolers when plant capacity was increased.

IN THE SYNTHETIC ammonia production department of a fertilizer plant three coolers of the so-called "open box" type were in use for cooling reaction-products of the synthesis of ammonia. (See Figure 1) Very brackish cooling water was used from a nearby canal that communicated via sluices with the open sea.

Very severe corrosion of the cooling tubes was experienced because of the high oxygen content, the turbulent flow and the temperature gradient along the cooling tubes. This corrosion manifested itself as very concentrated pitting and, in the course of a year, the tubes were corroded to such an extent they had to be replaced by new ones. During the replacement the cooler had to be shut down.

Corrosion products in the pits consisted of loose light-brown rust which could be removed easily leaving a clean metal surface, a typical result of highly concentrated anodic corrosion. The deep pit penetration was dangerous because the pressure of the gas in the tubes was 280-300 atmospheres. Replacement with cupro-nickel tubes was, apart from their considerably higher cost versus steel, impossible because this material cannot be used with moist gas containing ammonia.

So an experiment with cathodic protection was conducted on one of the coolers. A choice had to be made between protection by galvanic anodes and by impressed currents. Protection with magnesium galvanic anodes would be difficult because the space between tubes was too small to allow them to be inserted vertically. Figure 2 shows it was possible to insert these anodes horizontally between the bends of the tubes. Also in order to mount the anodes the cooler would have to be shut down and even then considerable difficulty would be met because the concrete box could not be dismantled. In addition, it was to be expected that (especially in the warmer areas of the cooling water) the anodes would need replacing after six months' use at the most, which would cause another shut down.

For these reasons protection with impressed current and inert anodes was decided upon. The anodes were of graphite, 900 mm in length, 108.4 mm wide and 22.6 mm thick. The advantage of using these anodes was that as long as the current density remained below 5 amperes per sq. meter (approx. 0.5 amperes per sq. ft.) of anode surface the attack on the anode is very small. Thus the numerous replacements of steel anodes were eliminated.

The graphite anodes were hung vertically between the tubes (See Figure 3). The upper part of the

anode was fitted with screw and nut between two bronze plates, the latter remaining above the water level. The anodes rested on the bottom of the box, whereas their top was kept in position by wooden beams laid across the box. On every anode two rubber rings were fitted to prevent them from short-circuiting against a cooling tube. Across the anodes a copper cable of 7 sq. mm cross section was laid contacting every anode via the screw and nut.

The cooling surface of the cooler being 51 sq. meters (550 sq. ft.), it was estimated that 500 milliamperes per sq. meter of surface to be protected would be sufficient to give complete protection. This would require a maximum current of 15 amperes. This current was divided among 21 anodes, so that

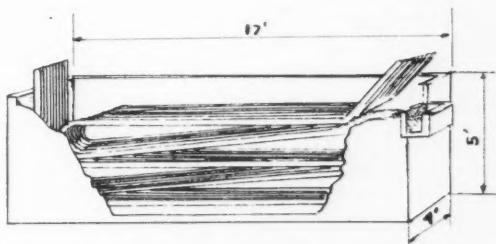


Figure 1—Open box cooler on which experiment was started.



Figure 2—Protection with magnesium anode.

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* With Messrs. Merrem & LaPorte N. V., Amsterdam, Holland.

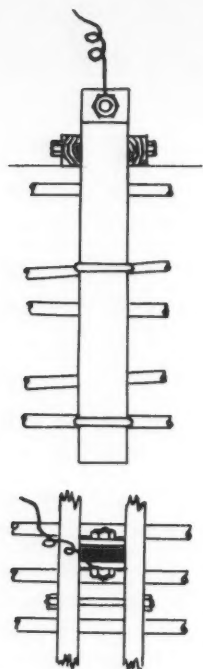


Figure 3—Fastening of graphite anodes.

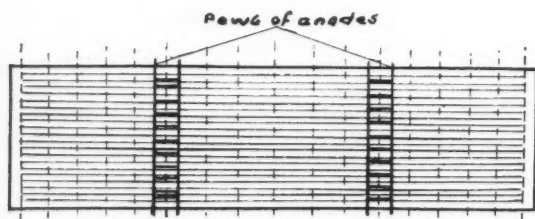


Figure 4—Position of anodes.

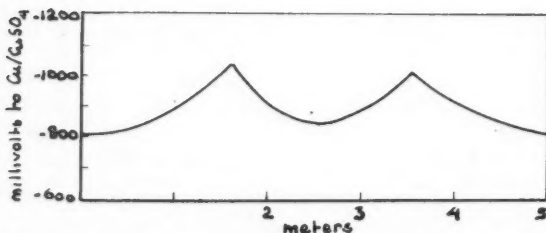


Figure 5—Potential obtained immediately after protection was applied at 14.5 amperes.

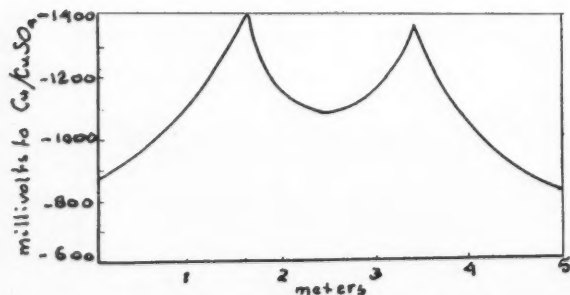


Figure 6—Potential obtained after four weeks of protection.

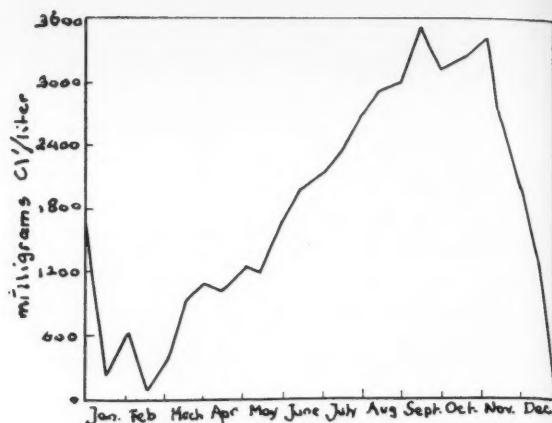


Figure 7—Salt content of cooling water.

the maximum current-density per square meter of anode surface would be about 3 amperes, which is permissible. The 21 anodes were installed into two parallel rows of 10 and 11 anodes respectively. (See Figure 4) As there was only a space of 10-15 cm ($\frac{3}{8}$ - $\frac{5}{8}$ inch) between the anodes and the tubes, it was to be expected that the current distribution over the tubes would be uneven. However, the very low resistivity of the cooling water (about 100 ohm. cm) was a favorable condition. A 12-volt 15 ampere selenium rectifier was chosen and connected to 220-volt single phase alternating current. The negative terminal of this rectifier was connected to one of the cooling tubes and all cooling tubes were bonded electrically with each other.

Before cathodic protection was applied, potential of the cooling tubes to the cooling water in relation to the copper-sulfate half-cell was 670 millivolts. After application of a current of 14.5 amperes, potential measurements were taken at varying distances from the anodes, as shown in Figure 4 along the broken lines. It was found that the potential of points (e. g. cooling tube No. 1 and cooling tube No. 5) at equal distances from anodes were almost the same. As would be expected it made a material difference whether the half-cell was moved away from or toward the anodes. A safe maximum value of the pipe-potential -850 millivolts was adopted. Figure 5 shows the values found. From this it can be seen that the figure of -850 millivolts was not attained everywhere. It was expected however the potential would become more uniform after a time.

Potential measurements were taken after four weeks, during which a deposit of salts formed on the cooling tubes opposite the anodes. This deposit was so heavy that the space between the anodes and the tubes was almost completely filled. At a short distance from the anodes, however, the salt-deposit stopped abruptly. It had been originally expected that this deposit would occur along the entire tube length, though somewhat heavier at the places immediately opposite the anodes. This deposit would be advantageous in that it would reduce the current to be delivered by the rectifier. On the other hand, cooling capacity of the tubes simultaneously would be reduced.

After the potential measurements were taken it was found that the pipe potential had considerably diminished since the first measurements and that it was more negative than -850 millivolts everywhere (See Figure 6). Inspection indicated corrosion on the tubes had stopped. The patches of light brown rust had disappeared and the silvery white metal that had appeared after removal of the rust two weeks before now had a dull and dark appearance. In order to save current, but principally to reduce the undesirable deposit it was decided to reduce the current to 12 amperes.

After another five weeks potential measurements were made again. Notwithstanding the reduced current, it was found that the pipe potential was further reduced and that the deposit of salts had decreased. Once more the current was reduced, this time to 10.25 amperes and at the same time both rows of anodes were moved out to produce better potential distribution.

Potential measurements were repeated at regular intervals and finally the current was reduced to 9.5 amperes. At this value corrosion appeared to have been stopped entirely.

Six months after application of cathodic protection corrosion suddenly started again in the middle between the two rows of anodes. It appeared that the potential of the tubes at this point had increased to -780 millivolts because resistivity of the cooling water had increased. Composition of the water varied with the seasons and with the letting in or out of water through the sluices, the latter influenced by the seasons. About January the salt-content of the water was at its minimum and hence resistivity at its maximum. See Figure 7. The current was raised to 11 amperes and the distance between both rows of anodes was slightly reduced. This incident established the value of the pipe potential at which corrosion started, namely between -780 and -820 millivolts. Except for this incident no further corrosion occurred during 14 months. The other two unprotected coolers were repaired several times during the same period. The graphite anodes showed some attack, their thickness decreasing from 22.6 mm to 19.4 mm and their width from 108.4 mm to 103.3.

In the meantime, the production of ammonia having been increased, the capacity of the three coolers appeared to be insufficient and it was decided to build four larger coolers, three with cooling surfaces of 80 sq. meters (880 sq. ft.) each and the fourth with a cooling surface of 90 sq. meters (990 sq. ft.) (See Figure 8). The three coolers already in use were to be shut down.

In view of the good results obtained with the cathodically protected cooler, it was decided to apply the same system of protection to the four new coolers. The box of these new coolers being of steel, the total surface to be protected would be 80 square meters + 28 square meters (surface of the box = 108 square meters for each of the first three coolers and 122 square meters for the fourth cooler. These coolers had very little space between the tubes, so the graphite anodes could not be placed vertically as was done with the first protected cooler. Moreover, the length

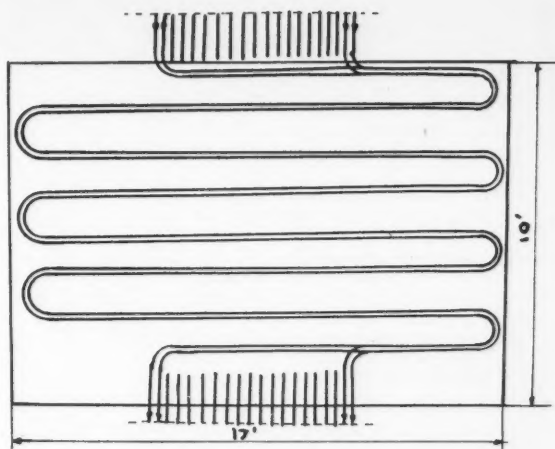


Figure 8—Front view of new cooler.

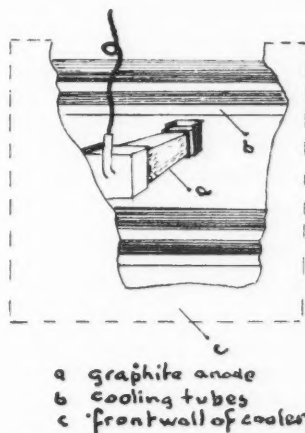


Figure 9—How anodes were fastened in new coolers.

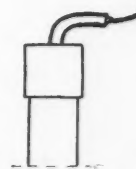


Figure 10—Rubber cap on end of anode.

of the anodes required would exceed the length at which these anodes can be produced satisfactorily. The anodes were installed horizontally between the front and back wall of the box thus crossing the bends of the tubes. (See Figure 9). Because the front plate of the box had to be removed to do this the installation could not be carried out while the cooler was in service, making it imperative to use anodes which would not need inspection during several years after installation. For this reason 2-inch square section anodes of impregnated graphite were chosen, this type having longer life than ordinary graphite anodes. The cables carrying the current had to be inserted absolutely watertight into the anodes because the anodes would be completely immersed. Ends of the anodes were fitted with heavy rubber caps and placed to rest in trays, which were welded inside the front and back walls. The rubber cap, on the end where the cable entered the anode was fitted with a rubber trunk through which the cable was drawn in order to prevent it making a sharp bend with the anodes (See Figure 10).

The shortest distances between anodes and cooling tubes was 60 mm, so better current distribution was expected than with the old coolers, where the dis-

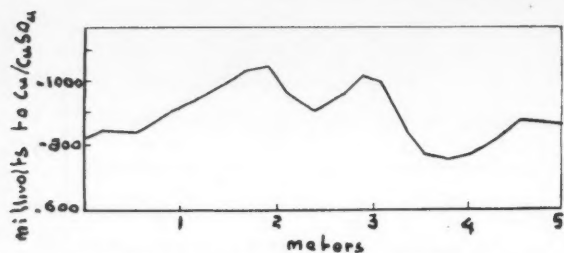


Figure 11—Potential obtained on new coolers immediately after protection at 21 amperes.

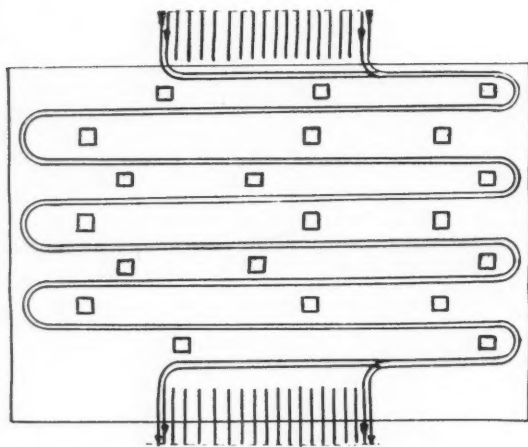


Figure 12—Position of anodes in new coolers.

tance was only 10 to 15 mm. An average current density of 200 millamperes per sq. meter surface to be protected was therefore considered to be sufficient. In this way, 21 amperes was needed for each of the three smaller coolers and 25 amperes for the large one.

Selenium rectifiers rated at 12 v, 25 amperes were chosen as the source of direct current. The positive

terminal was connected to a copper bar on top of the coolers to which all anode cables were led. For the three small coolers it was estimated that 20 graphite anodes would be sufficient and that for the larger one 24 would do. The current density would be about 3 amperes per sq. meter anode surface. The negative terminal was connected with one of the cooling tubes, which were bonded electrically.

In the meantime the three smaller coolers were put into service. After some weeks their tubes showed very severe pitting. Two of these coolers are protected. The potential of tubes in the unprotected coolers was -620 millivolts. Immediately after the cathodic protection was applied, this potential at 21 amperes decreased to a value indicated in Figure 11. Complete protection was not obtained at once.

Further measurements taken after three weeks, showed the potential had decreased and that apparently the corrosion had stopped. After another three weeks, the potential was still lower and complete protection had been obtained everywhere. Again there was some deposit on tubes in the vicinity of the anodes, much less however than was the case with the old coolers because the distance between anodes and the tubes was greater.

The third smaller cooler which could not be fitted with the protection had to be taken out of service after 15 months when penetration of the tubes had occurred due to corrosion.

The fourth cooler, not yet in use, was designed for application of the protection from the beginning.

Distribution of the anodes in the two protected coolers is given in Figure 12.

Concluding, it can be said that cathodic protection of open box coolers is possible and that it is a sound remedy against corrosion of the cooling tubes.

This work was carried out by Messers Merrem and LaPorte, N. V. Concessionaires for the Guardian system of cathodic protection.

Important Advantages of Titanium In the Chemical Industry*

By W. G. RENSHAW and PERRY R. BISH

PPOTENTIALITIES of titanium as a material of construction for the chemical industry are quite promising but its use in this field has been restricted by short supplies and high prices. Strategic applications which gave impetus to the development of this metal receive first call on both research and production facilities. Facilities of the Titanium Metals Corporation of America (owned jointly by Allegheny Ludlum Steel Corporation and National Lead Company) and of other producers are being greatly expanded and there is a possibility that the metal soon may become more and more available for nonmilitary uses. The present price will, of course, have to be lowered and to accomplish this, a simpler reduction and melting process will have to be found.

Original attractiveness of titanium lay in its usefulness as a load bearing structural material for aeronautics where its high strength/weight ratio was most advantageous. The demand for a metal having desirable properties for such purposes obviously would be very great and private industry became intrigued with its possibilities despite the difficult chemical and metallurgical processes involved in its production. Success of its efforts is reflected in the progress which has been made. Today titanium is close to commercial realization in that almost every form of wrought material—plates, sheets, bars, wire, forgings, etc.—is in regular mill production in fairly large quantities. The excellent corrosion resistance of titanium later became an added incentive for commercial development, but until the demands for strategic applications are met, research will be almost exclusively directed toward high strength alloys for aeronautical uses or those with high impact strength for ordnance applications. There will probably be little consideration given to the specific needs of the chemical industry or to nonmilitary uses for some time. However, the corrosion resisting characteristics of titanium should be of interest to the chemical industry in the event that overnight developments cause a marked change in availability and price.

There are no alloys of titanium available today with any special properties of interest to the chemical industry. The commercially pure grade of the metal is resistant to a wide range of corrosive substances and is superior to other metals under certain special operating conditions. It is in these special cases that titanium can pay its way satisfactorily because of certain inherent corrosion resisting characteristics not shown by other materials. The data

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PERRY R. BISH—Now employed in the Chemistry and Corrosion Section of Allegheny Ludlum Steel Corporation's Research Laboratory. He spent two years in the Chemical Corps, U. S. Army and is a 1950 graduate of Grove City College with a BS in chemical engineering. He is a member of the American Chemical Society.



Abstract

Valuable properties of titanium are discussed with emphasis on its good resistance to specific types of corrosion, including pitting, stress and intergranular corrosion. Titanium's influence in making design problems simpler is discussed.

Passivity of titanium under oxidizing conditions resembles that of certain other metals but is distinctly different under some conditions. Some conditions which promote passivity and a stable passive state are discussed. Inhibitors are unusually effective in certain corrosive media where other passive metals are not benefited. Studies of titanium's passivating characteristics and the presence or absence of certain components in the environment may explain behavior of the metal in dry halogens and certain other media. Moist environments appear to be conducive to passivity while the reverse is often true for other metals in some of these severe applications.

shown in this paper were obtained on commercially pure titanium 75A, produced by the Titanium Metals Corporation of America.

Physical and Mechanical Properties

In designing chemical equipment the physical and mechanical properties of materials are significant. Selection of a material frequently is guided by these properties, especially when several different metals have adequate corrosion resistance for a particular application. Table 1 shows the physical properties of titanium.

*A paper presented at the Tenth Annual Conference, National Association of Corrosion Engineers, Kansas City, Mo., March 15-19, 1954.

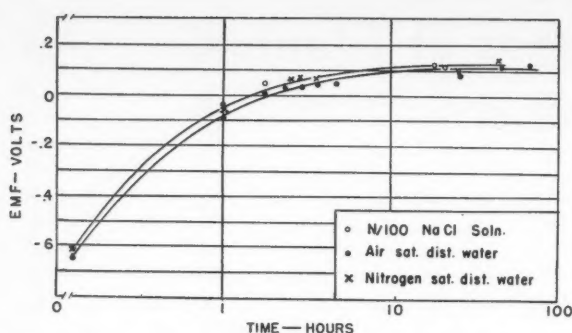


Figure 1—Passivation of Ti 75-A in N/100 sodium chloride and distilled water.

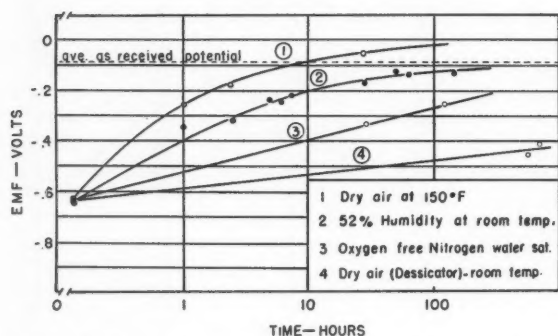


Figure 1A—Effect of moisture on passivation of commercially pure titanium (Ti 75-A).

TABLE 1
Physical Properties of Commercially Pure Titanium

Melting Point.....	Approx. 3135° F (1725° C)
Specific Heat.....	.13
Density.....	.16 lb./cu. in. (4.57 g/cc)
Thermal Conductivity.....	92-118 BTU/hr/ft. ² /°F/in. (.032—.041 CGS)
Electrical Resistivity.....	50 Microhm—CM
Coefficient of Expansion.....	$5.6 \times 10^{-6}/^{\circ}\text{F}$ ($10 \times 10^{-6}/^{\circ}\text{C}$)

TABLE 2
Mechanical Properties of Annealed Titanium

Modulus of Elasticity.....	16,000,000 psi.
Yield Strength (0.2 percent Offset).....	60,000—90,000 psi.
Tensile Strength.....	75,000—100,000 psi.
Elongation in 2 inches.....	15—25 percent
Hardness.....	85—85 Rockwell B
Impact Strength (V-Notch at 100° F).....	15—25 ft. lb.

Density is about 60 percent of ferrous materials and is only 60 percent greater than aluminum. While specific heat, thermal conductivity and electrical resistance are all strikingly similar to austenitic stainless steel, titanium has much lower expansion properties—only about $\frac{1}{2}$ as great.

Mechanical properties are shown in Table 2. These properties are typical for the commercially pure titanium available at present.

General Corrosion Resisting Characteristics

Actually very little service information is available, because for obvious reasons no material has been obtainable for chemical applications. There are many attributes which should make titanium outstanding but these have been indicated by laboratory tests. In discussing the place of titanium in the

chemical industry it would be premature at this time to compare it with other useful materials like lead, aluminum, nickel, copper and stainless steel. At present prices, titanium is only of value where it can pay its way. Therefore, this discussion is based on certain conditions where titanium is most advantageous and where there is some agreement as to its behavior. It would be folly to consider actual corrosion rates as a basis for comparisons, because differences in manufacturing methods cause variations from lot to lot of material in corrosion tests. Furthermore tomorrow's titanium will be vastly improved over that of today, because of constantly improved refining, melting and finishing techniques.

Titanium has an anomolous set of corrosion characteristics. It is inherently reactive chemically, standing between beryllium and magnesium in the EMF series, yet its corrosion resistance is considerably better than its position would indicate.

Neutral or Oxidizing Environments.

In order to point out wherein some of the advantages of this metal lie, a knowledge of its general behavior and the conditions responsible for its outstanding corrosion resistance should be of value. Titanium exhibits a passive surface condition in neutral or oxidizing environments, which places it in the same category as certain other widely used materials of construction. It readily passivates in air and is in its best corrosion resisting condition under these circumstances.

Figure 1 illustrates the general passivating tendencies of titanium in liquids. Curves for N/100 sodium chloride and distilled water saturated with air or nitrogen all follow each other very closely. Potential measurements were all made in N/100 sodium chloride using the saturated calomel electrode as a standard. All specimens employed had a standard 2B commercial finish. They were thoroughly degreased with an organic solvent and then activated in a 1:1 hydrochloric acid solution at 180 F until a uniform active potential was attained ($-.62$ volts referred to the saturated calomel electrode in N/100 sodium chloride solution). This same procedure was employed for all the succeeding measurements. Indications are that oxidizing or neutral conditions are conducive to passivity of the metal, but where reducing acids like hydrochloric are involved the potential becomes less noble,¹ and attack can occur.

Effect of Moisture

The effect of moisture in an air or nitrogen environment may be significant as illustrated by data in Figure 1A. In carrying out these tests it was necessary to employ a liquid electrolyte to determine the potentials. Because it was observed in Figure 1 that exposure to N/100 NaCl could contribute to passivity, specimens were immersed only once for measurements and then discarded. Each point on the curve represents a different test specimen. As received potentials of titanium average about $-.08$ volts prior to activation. Curve 4 in Figure 1A indicates that passivation is very slow in dry air, with a change of

only .25 volts toward the noble side in 100 hours. In contrast at a controlled humidity of 52 percent in air, there is a marked increase of .45 volts more noble in only 10 hours. The absence of attack with moist chlorine gas, but severe corrosion when dry, probably is related to this behavior. The formation of hydrated oxide films which are dense and protective in nature might account for the good corrosion resistance of the metal in most environments. Adsorption of gases on the surfaces may, however, be partially involved as shown by Curve 3, representing the potential changes resulting from exposure to moist nitrogen gas which is oxygen free and by Curve 1 which shows fairly rapid passivation in dry air at elevated temperatures. Whether oxide films are an explanation of passive behavior in titanium has not been conclusively shown by any investigators. It is known that heavy oxides similar to those formed on aluminum can be produced by anodizing.

It is this inherent passive characteristic which gives a metal that would otherwise be very reactive a noble potential and good corrosion resistance under many conditions. In general it has been established that titanium is most resistant under oxidizing conditions. For example, the addition of small percentages of nitric or chromic acid to sulfuric will inhibit attack completely.² Similarly oxidizing agents are also effective in hydrochloric acid,^{2,3} and copper in phosphoric acid prevents attack.⁴

Application of Titanium to Chemical Processing

One of the most promising uses for titanium is in handling of chloride salts. It has exceptional resistance to corrosion in sea water and other brines; it is practically unaffected by other vicious corroding agents like ferric, stannic or mercuric chloride and the hypochlorites. In very dilute solutions of hydrochloric acid (up to about 2 percent) very low corrosion rates are found and it is also possible by the addition of inhibitors to extend its range of usefulness to high concentrations of this acid. For example, the addition of nitric acid completely inhibits attack, thus titanium is one of the few metals resistant to aqua regia. Chromates and copper sulfate also have an inhibiting effect when present in the acid in small amounts.

Effect of Inhibitors

Table 3 shows the effect of these inhibitors in 5 percent (by weight) hydrochloric acid at 200 F (94 C). It has been shown also that the addition of various metal ions to 1 N hydrochloric acid can inhibit attack, and that the potential of titanium in solution becomes increasingly noble with the more noble metal ions added.⁵ It has been reported also that aniline hydrochloride produces negligible attack in a 20 percent solution as high as 212 F (100 C),⁶ indicating organic inhibitors might be useful in some cases. Additional research undoubtedly will uncover many other compounds that have a similar effect.

While dry chlorine gas cannot be handled by titanium, there is indication that even small traces

of moisture are beneficial. It has been found that when more than .013 percent water is present no reaction occurs between titanium and chlorine.⁷ Moist chlorine gas has been a problem with other corrosion resisting metals but titanium offers a possible solution to this difficulty.

Supplementing its resistance to straight chemical attack, additional advantages over the metals used in chloride service may be realized. With most other metals, equipment must be carefully designed and operating conditions controlled to avoid troubles from causes other than direct attack. For example, the nature of chloride solutions may be affected by stagnant conditions which lead to pitting. Contact with nonmetallic gasket materials or the presence of crevices produces a similar result. Susceptibility to stress corrosion cracking is another hazard. Since these effects are inherent in a process or design, titanium may be of particular value because of its unique corrosion resisting characteristics under such exposure conditions.

Resistance to Pitting

Pitting or localized surface attack, a source of difficulty with practically all metals in certain appropriate environments, is resisted extremely well by titanium under nearly all conditions. In chlorides the metal offers its most promising possibilities. Even in severe pitting reagents such as ferric chloride and cupric chloride or hypochlorites, accelerated laboratory tests provide strong evidence of the exceptional resistance to pitting. Exposure of the metal to strong solutions of these for prolonged periods has not caused any indication of attack. In comparison several other corrosion resistant materials were severely pitted in a short time. Experience with immersion tests in ferric chloride and hypochlorites provides a background for predicting the susceptibility of highly corrosion resisting metals to pitting in other milder chloride solutions or brines. The complete absence of any form of corrosion on the titanium samples, particularly after an exceptionally long testing period is a criterion of its superior performance in chloride applications.

Whereas with other passive type metals chloride ion has a tendency to destroy passivity of the surface and to support the localized attack or pitting by the formation of soluble chlorides, it is probable that in the case of titanium, the chloride instead hydrolyzes readily to form an hydroxide. This would not be expected to maintain an active condition at the localized areas and thus pitting never has an opportunity to propagate.

TABLE 3
Corrosion Rate of Titanium in Inhibited 5% HCl at 200° F.
(Inches Per Month)

Percent Added	Copper Sulfate	Chromic Acid	Nitric Acid
None.....	.023	.023	.023
.05.....	.0003	....	....
.50.....	.0002	.0001	....
1.00.....	.0002	.0001	.0003
5.00.....	.0002	.0001	.0003
10.00.....	....	....	.0004

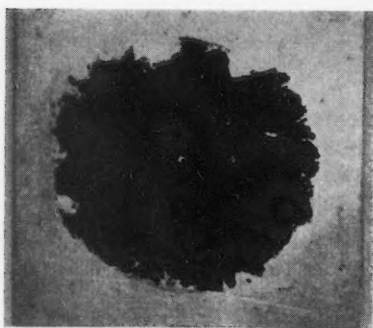


Figure 2—Test sample with graphite on the surface.

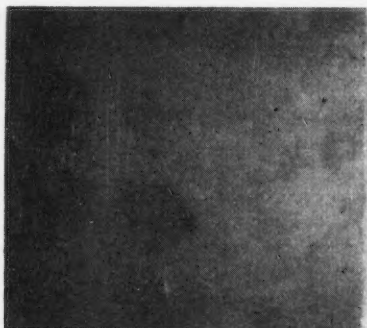


Figure 3—Titanium sample after testing with graphite in salt spray for 30 days.



Figure 4—Titanium sample tested with rubber band attached after six weeks in 5 percent salt solution.



Figure 5—Spot welded titanium sample exposed to 5 percent salt solution for six weeks.

Resistance to Contact Corrosion

In addition to the good resistance to pitting by chlorides, there are certain other types of corrosion which do not affect titanium. Stagnant conditions, surface deposits, fouling marine organisms and moist salt crystals are not troublesome to titanium. With many other passive type metals electrolytic cells under surface deposits or contamination often contribute to rapid pitting. Laboratory tests pictured in Figures 2 to 4 very suitably illustrate the resistance of titanium to contact corrosion. Graphite was selected for the test shown in Figures 2 and 3, since it is commonly employed in gasket or packing materials but has in a number of cases been troublesome with metals from the standpoint of localized corrosion of flanges and other facing surfaces. It stands just below silver and near the bottom of the galvanic series and therefore would be expected to cause accelerated electrolytic pitting and attack on metals above it in the series. Titanium is completely unaffected after 30 days' exposure in a 20 percent salt spray with powdered graphite on the surface (Figure 2). Figure 3 shows that pitting was absent beneath the deposit.

Other gasket materials may involve rubber. In certain environments, especially chlorides, this may promote contact corrosion with some metals. Again the superiority of titanium under contact conditions is illustrated by the test specimen in Figure 4. A rubber band was stretched tightly lengthwise on the titanium sample immersed in 5 percent sodium

chloride for six weeks. No attack was observed at any point of contact. The significance of these tests is apparent when gasketed joints are involved and the excellent behavior of titanium as illustrated indicates far less maintenance will be required in equipment which must be taken apart frequently.

Less Vulnerable to Crevice Corrosion

Still another kind of localized corrosion which may take place even in the absence of chloride is that associated with crevices. From a study of this it would appear that titanium is less vulnerable to the common troubles associated with crevices. Samples of titanium spot welded to form a crevice, as shown in Figure 5, showed no evidence of localized corrosion after six weeks in 5 percent sodium chloride. Other metals frequently suffer severe pitting and localized corrosion where crevices exist. Once the oxygen concentration cell has initiated attack, then differential metal ion concentration cells also start to operate and cause even more severe attack. As crevices are the most active form of oxygen concentration cell, the tests simulate many other design problems which may initiate or accelerate localized attack. Joints involving seams or crevices can be employed safely and where titanium is used as lining in tanks for example, it will not suffer accelerated localized corrosion if moisture condenses in the zone between the titanium liner and the tank wall or if liquids should splash over the top and seep into the opening. Designing equipment to avoid these hazards is, therefore, simplified in the case of titanium.

There has been no tendency toward stress corrosion cracking of titanium in chloride solutions which are capable of producing failure in some other metals. Boiling magnesium chloride, ferric chloride, sodium chloride plus hydrogen peroxide and aqua regia have been completely without effect on stressed laboratory tests.^{8,9}

Effect of Residual Stresses

It would appear that normal residual stresses resulting from fabrication seem to be less critical than in other materials of construction. This would be a decided advantage for example where complicated drawing and forming operations are involved and where annealing or stress relieving heat treatments are not practicable before chloride or many other types of service. Similarly with many metals welding also can cause sufficient residual stresses to induce this type of attack, but laboratory tests on welded titanium specimens have shown it to be resistant to cracking in a wide variety of chloride solutions.

Welding of titanium appears to have no deleterious effect on the corrosion resistance of the heat affected zones exposed to chlorides or other media. Furthermore, specimens aged at various elevated temperatures have not been found to be affected harmfully.

Resistance to Intergranular Attack

This can be of extreme value where special heat treatments might be specified. Where aging or stress relief may be required for another metal used in combination with titanium in certain types of construction no concern need be felt about harming the corrosion resistance of the titanium in such instances. To date no case of intergranular attack has been observed on commercially pure titanium, even, for example under such severe exposures as ferric chloride, or boiling 65 percent nitric acid. Commercially pure titanium does not seem to suffer any susceptibility to intergranular attack with heating, but this may not be the case with its alloys.

The results of these and numerous other tests indicate that titanium should be an excellent material for all types of equipment handling chlorides, where complicated fabrication may induce sufficient residual stress to cause cracking, or where localized corrosion or pitting is a problem due to crevices, deposits on the metal surface or other contributing causes. It should provide a better material for crystallizers, filter screens and plates, driers and conveyors in the processing of sodium, magnesium or calcium chloride and sodium or calcium hypochlorite. It can be used in condensers using brackish cooling water. Titanium will be of exceptional advantage to handle bleaching of paper pulp and textiles where hypochlorites or moist chlorine is involved. With the increased use of chlorides in the dyeing of synthetic textiles, titanium should prove useful in all types of dyeing equipment. The excellent resistance to aqua regia and ferric chloride should provide more simple metallic equipment for strong etchants in the name plate and lithographic industry. Compared to conventional corrosion resisting materials, titanium and titanium alloys should be outstanding in these and similar applications.

In Nitric and Chromic Acids

A second important field for titanium and titanium alloys concerns certain strongly oxidizing agents such as nitric acid, fuming nitric acid and chromic acid. While there are several materials available which will handle these reagents at moderate temperatures or in dilute solutions it becomes more difficult to obtain satisfactory metallic equipment for the higher temperatures and high concentrations. Titanium has excellent resistance to all concentrations of nitric acid. Its corrosion rate in red and white fuming nitric acid is practically negligible and it is unaffected in highly concentrated solutions of chromic acid. Table 4 shows the corrosion rates of commercially pure titanium (TMC 75A) in nitric acid.

Beck and Fontana¹⁰ also report the corrosion rate

of cast titanium in nitric acid at elevated temperatures and pressures is less than .005-inch per year. It has been reported¹¹ that a filter of titanium has performed satisfactorily in red fuming nitric acid at 160 F.

Laboratory testing has also provided data on welds in boiling 65 percent nitric acid with a welded titanium tank. This vessel was constructed for the purpose of carrying out corrosion tests on other types of metals immersed in the boiling acid. It was thought that titanium would make a desirable material of construction, because it exhibited only very slight attack by nitric acid and the pickup of contaminating metal ion in the acid would, therefore, be slight. A water cooled condenser was employed with the tank. After approximately 1440 hours of service there was no indication of accelerated attack at the titanium welds or heat affected zones and the base metal showed negligible attack although it was darkened somewhat. Only slight staining was observed in areas in the vapor phase.

It would appear from these data that titanium should be highly useful for absorbers, heat exchangers, storage tanks and various processing accessories in the manufacture of nitric acid and for equipment in the manufacture of dyes and explosives involving fuming nitric acid. Its excellent resistance to chromic acid indicates possibilities in the tanning industry and in the manufacture of lithographic and printing inks.

For Acetic Acid Service

For obvious reasons, the two previously mentioned corrosive conditions have received the most attention and considerable research remains to be done in other fields where presently available materials are not satisfactory either from a standpoint of resistance to attack or high maintenance costs. For example, there is need for a better material for acetic acid service at high temperatures. Laboratory tests indicate that titanium is resistant at boiling temperatures but little is known about the behavior in severe acetic acid environments. A service test confined to easily fabricated parts such as bubble caps and trays in the hot end of fractionating and rectifying columns would provide valuable information on the utility of titanium in acetic acid processing. Similarly some promise shown in laboratory tests in lactic and tartaric acid, phenols and chlorinated hydrocarbons indicate service tests in these cases would develop useful information.

Resistance to Sulfur

Resistance of titanium to molten sulfur and sulfur compounds points to some merit in various troublesome conditions associated with handling these materials. Moist gases containing sulfur dioxide or hydrogen sulfide often cause localized attack in the usual materials of construction, particularly in the zone of condensation. Consideration of titanium in these cases would not be amiss because of its good resistance to such attack. Solutions of sulfuric acid, unless inhibited by an oxidizing agent, should not be

TABLE 4
Corrosion Rates of Titanium in Nitric Acid

65 Percent HNO ₃ Boiling	.0001—.00015
Red Fuming HNO ₃ , Room Temperature	.000.005—.000.007
White Fuming HNO ₃ , Room Temperature	Negligible 14 months

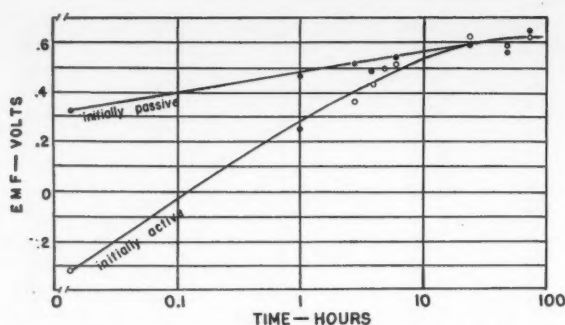


Figure 6—Passivation of commercially pure titanium (Ti 75-A) in 30 percent nitric acid.

included. The fact that most corrosion products of titanium are colorless may avoid bothersome staining of sulfite paper pulp should some superficial corrosion occur. In this regard, titanium screen plates, pulp blenders, save-alls and similar paper-making accessories may be advantageous.

Phosphoric and Hydrochloric Acids

These are but a few of the potential uses of titanium in the chemical industry and there is much to be learned about titanium before its fullest advantages can be appreciated from the standpoint of chemical equipment. There are some conditions in which titanium may not satisfy and some applications in which it will never supplant existing materials in use. For the present titanium shows no promise in phosphoric acid applications or where highly concentrated hydrochloric or sulfuric is involved. The development of alloys or modifications to overcome these deficiencies should eventually receive attention.

Fabricating and Maintenance Advantages

Considering fabrication, the commercially pure grades are more easily handled than any of the alloys developed to date. These grades are sufficiently ductile to respond well to cold forming operations such as drawing, stamping, forming and spinning. This is an important factor in considering the manufacture of corrosion resisting equipment, because while there often are several materials of similar corrosion resistance for applications some may not form easily or may not be available except in cast shapes. It is here that titanium also can command attention in spite of price, because fabricating difficulties and costs may eventually make it cost far less than a less expensive construction material.

Titanium is easily spot welded with conventional equipment and resistance welding poses no problem. Ductile welds can be made on commercially pure grades using inert gas shielded methods. As suggested before, commercially pure titanium apparently does not suffer loss of corrosion resistance at the heat affected zone from welding. Consequently, annealing treatments are not necessary to restore its corrosion resisting properties, a step which is essential with some other metals of construction. For applications involving chlorides, stress relieving heat treatments would not be needed to prevent stress corrosion

cracking. Where specifications designate such heat treatment, no danger of precipitating harmful phases is encountered which could cause susceptibility to accelerated attack. Because of the absence of crevice corrosion susceptibility, design can be simplified considerably. A highly finished surface, free of marks by tools or gauges, etc., probably is not essential for the same reasons.

While maintenance problems are greatly lessened with titanium because surface deposits or contamination do not contribute to localized attack, periodic cleaning of equipment usually is desirable to aid heat transfer, liquid flow rates, etc. In such instances deposits readily soluble in hydrochloric acid, for example, can be removed with no danger to equipment by using an inhibited solution. The removal of iron deposits left from tools, dies, etc., after fabrication can be accomplished with a nitric acid solution. Figure 6 illustrates the rapid trend toward a passive condition in 30 percent nitric acid, even with a freshly abraded or activated surface.

Recently there have been a few titanium lined steel vessels fabricated. Titanium is an ideal combination with mild steel, particularly where a final stress relieving heat treatment is required. The temperature needed to relieve residual stresses is relatively low for both metals and distortion is minimized because their expansion characteristics are almost identical. A vessel so fabricated can be stress relieved safely around 1100-1200 F without excessive scaling or distortion. With added experience in fabricating units of this type there is no reason titanium-lined vessels cannot be made available economically to the chemical industry.

References

1. M. E. Straumanis and P. C. Chen. The Corrosion of Titanium in Acids—The Rate of Dissolution in H_2SO_4 , HCl , HBr and HI , *Corrosion*, **7**, No. 7, 229-237 (1951) July.
2. W. W. Harple. Behavior of Titanium in Sulfuric and Hydrochloric Acid, Presented at NACE Conference, March, 1953.
3. Joseph R. Cobb and H. H. Uhlig. Resistance of Titanium to H_2SO_4 and HCl Inhibited by Ferric and Cupric Ions, *J. Electrochem. Soc.*, **99**, No. 1, 13 (1952) Jan.
4. Unpublished Data, Allegheny Ludlum Steel Corporation, Research Laboratories.
5. David Schlain. Certain Aspects of the Galvanic Corrosion Behavior of Titanium, Bureau of Mines Report of Investigations 4963, April, 1953.
6. R. Lane, L. B. Golden, W. E. Lusby. *Ind. Eng. Chem.*, **45**, No. 5, 1067-1070 (1953) May.
7. E. C. Fetter. Titanium—Good But Not Miraculous. *Chem. Eng.*, **57**, 263 (1950).
8. G. C. Kiefer and W. W. Harple. Stress Corrosion Cracking of Commercially Pure Titanium. *Metal Prog.*, **63**, 74-76 (1953) Feb.
9. H. H. Uhlig and J. R. Cobb. *Metal Prog.*, **61**, 816, (1951) June.
10. F. H. Beck and M. G. Fontana. Corrosion By Aqueous Solutions at Elevated Temperatures and Pressures. *Corrosion*, **9**, No. 8, 287-293 (1953) Aug.
11. *Chem. Eng.*, **60**, 105 (1953) Apr.

DISCUSSION

Question by William W. Wheeler, P. O. Box 672, Pasadena, Texas:

Do you have information about the resistance of titanium to reducing atmospheres at 2000 F?

Reply by W. G. Renshaw and P. R. Bish:

We have no data at this temperature. There are some indications that embrittlement from hydrogen can occur at elevated temperatures.

Question by F. L. Whitney, Monsanto Chemical Company, St. Louis:

What percent HNO_3 is necessary to inhibit 22 percent HCl at room temperature?

Reply by W. G. Renshaw and P. R. Bish:

We have not investigated every possible combination of hydrochloric acid and nitric acid in regard to inhibiting of attack and therefore cannot reply on this specific condition. Titanium is resistant to 3 parts hydrochloric plus 1 part nitric at room temperature. Considerable data on inhibiting hydrochloric acid attack with various compounds were presented in W. W. Harple's paper "Behavior of Commercially Pure Titanium in Sulfuric and Hydrochloric Acid" given at the Annual NACE Conference in Chicago in 1953. The paper has not been published.

Question by Lyle A. Timm, 17636 Matthews, Wyandotte, Michigan:

Use of titanium-clad steel would open vast new areas of economic use of titanium. Is work being done on titanium-clad and when will it be available?

Is wire filter cloth of titanium available and who is now making it?

Reply by W. G. Renshaw and P. R. Bish:

Work is being done on titanium-clad steel but it is not possible to say when such a product will become commercially available.

We understand that one company (Brush Development) has made some wire filter cloth from

titanium but do not know whether it is yet offered commercially.

Question by Garland M. Riegel, Republic Steel Corporation, Massillon, Ohio:

What chemical processes are taking advantage of the properties of titanium at the present time and what minimum thicknesses are being used for tank liners?

Reply by W. G. Renshaw and P. R. Bish:

At present the chemical processes in which titanium have been used are still very limited and details have not been made available to us.

Remarks by E. Richard Sprague, 16526 S. Caress Avenue, Compton 1, California:

North American Aviation reported in the MX-770 progress report to air force on September 15, 1953, a case of a titanium explosion in which regular nitric acid, not RFNA was involved. As I recall, the residue on the surface of titanium parts became impact sensitive and exploded following a regular cleaning in nitric-hydrofluoric acid.

Reply by W. G. Renshaw and P. R. Bish:

We have not in 3 years' testing experience encountered any instances of explosions with titanium either in red fuming nitric or boiling 65 percent nitric acids and therefore cannot add anything to this subject. We have heard there were several cases of such accidents, but believe that our success in avoiding them has been due to the fact that we do not permit any pressure to build up in closed systems.

[Editor's Note: See News Section, Page 18, CORROSION, Sept., 1954, for a report on the explosion of titanium in red fuming nitric acid at College Park, Md.]

Use of Organic Inhibitors In Refinery Distillation Process Equipment*

By G. E. PURDY

Introduction

ORGANIC corrosion inhibitors have been widely used since 1944 for the prevention of internal corrosion in producing oil and condensate wells. There has been considerable literature published describing the use of these inhibitors. Also, the minutes of the National Association of Corrosion Engineers Technical Committee I, on Corrosion of Oil and Gas Well Equipment have shown the wide acceptance of this type of treatment for prevention of corrosion encountered in the production of crude petroleum.

Since the inception of petroleum refining, the industry has been plagued by corrosion problems. Within recent years, this problem has been intensified by an increase in the processing of sour crudes and by the introduction of catalytic processes. Studies of corrosion attack to catalytic units have shown that in many cases the more severe problem occurs as hydrogen embrittlement and/or hydrogen blistering. Within the past three or four years, organic inhibitors have come to be generally used for the treatment of distillation equipment in refineries and gasoline plants. At present, over 150 refineries in the United States and some 20 foreign refineries, as well as a considerable number of gasoline plants are protecting equipment of various kinds with an organic corrosion preventive, which will be described.

Chemical Properties

The inhibitors employed in obtaining the results presented in this paper are marketed under the trade name Kontol.

U. S. Patents Nos. 2,366,517; 2,466,530; 2,598,213; 2,640,029 and Reissue Patent 23,227 are concerned with the prevention of corrosion and describe these inhibitors.

In a general way, the inhibitors described in these patents are non-volatile high-molecular-weight poly-amino compounds having one or more characteristic hydrophobe radicals.

These organic compounds are particularly effective as corrosion inhibitors for several reasons. For one thing, the nitrogen-containing polar portion of the molecule is strongly attracted to polar surfaces, particularly metallic surfaces, forming an adsorbed impervious protective film. The adsorption of this film can be accomplished where the oil-soluble compound is present in hydrocarbon in concentrations of only a few parts per million, at temperatures up to 450 F. It is significant, too, that this film is only very slowly deabsorbed, thus providing protection over considerable periods of time.

These compounds also have the advantage of being

G. E. PURDY—Senior Technical Service Engineer for Tretolite Company Division of the Petrolite Corporation, specializing in application of organic inhibitors in the petroleum and allied industries. A graduate of Missouri School of Mines in Metallurgy, while in the Army from 1942 to 1946 he attended the Universities of Idaho and Utah where he studied mechanical engineering. After leaving the Army he re-entered Missouri School of Mines where he received a degree of BS in chemical engineering, 1947. He was employed by the General Chemical Division, Allied Chemical and Dye Corp., East St. Louis, Ill., before joining Tretolite.



Abstract

Use of a high molecular weight organic corrosion inhibitor is discussed. Recommended methods are given for use to inhibit losses from such corrosives as hydrogen sulfide, hydrochloric acid, organic acids and salts. Secondary effects are explained, such as detergent effects, which make for less cleanup time and for maintenance of designed heat transfer characteristics. Experiences in 120 refineries in the United States and Canada and 14 refineries in other countries are reviewed.

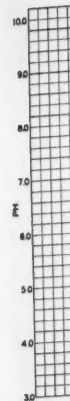
relatively inert to other substances. For example, they have little or no effect on the various catalysts used in refining. These inhibitors, in general, do not react with chemical washes or treatments to which the hydrocarbons are conventionally subjected. The effectiveness of caustic washes, doctor-treating, sweetening and other treatments usually is not affected by the presence of the inhibitor. Also, because these inhibitors contain both hydrophilic hydrophobic groups, they are distributed in both oil and water and provide protection in both phases.

Method of Treatment

The method of treatment will vary depending upon the type of equipment to be protected. For example, in protecting distillation overhead vapor systems, since the inhibitor is non-volatile, it is necessary to inject the chemical directly into the overhead vapor line. The oil-soluble inhibitor is carried by the vapors, dissolves in any condensed hydrocarbon and is distributed over all subsequently disposed internal metal equipment, such as lines, heat exchangers, condensers, reflux drums, etc. Because a large portion of the condensed hydrocarbon is returned to the tower as reflux and because the inhibitor is soluble in hydrocarbon, enough inhibitor is returned to the top of the tower to provide protection by refluxing downward in the tower until a temperature of 450 F is reached.

It is usually recommended that the inhibitor be injected continuously by means of a small chemical proportioning pump. Normally, the inhibitor is di-

*A paper delivered at a meeting of Western Region, National Association of Corrosion Engineers, Los Angeles, Cal., November 19-20, 1953.



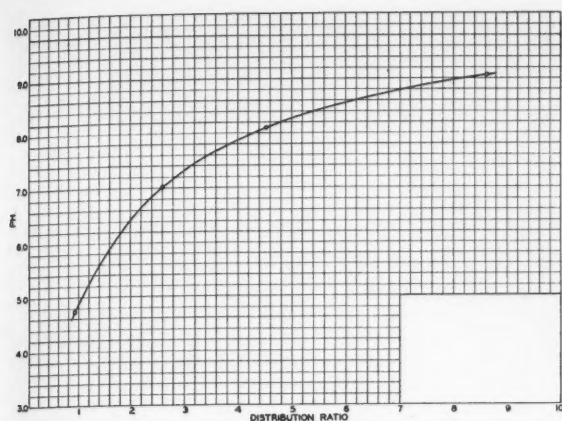


Figure 1—Oil-water distribution ratio of inhibitor.

TABLE 1
Effect of pH Control

Date	Crude	pH	Iron (ppm)	REMARKS
1951				
9-2	Replaced Carbon Steel Line			
11-17	Kuwait	9.0	15.5	pH Control Only
11-21	Tucupido	8.2	3880.0	
11-23	San Joaquin	8.6	70.3	
11-27	San Joaquin	8.5	369.0	
11-30	San Joaquin	8.9	50.6	
12-3	San Joaquin	8.4	50.8	
12-5	San Joaquin	5.3	204.0	
12-6	San Joaquin	8.8	53.0	
12-20	Replaced Carbon Steel Line Installed			9-2-51
1952				
1-4	Tucupido	8.8	4.4	Inhibitor* Only
1-7	West Texas	5.1	299.0	Inhibitor Detergent Action
1-8	West Texas	5.1	788.0	
1-9	West Texas	6.1	2478.0	
1-11	West Texas	4.9	468.0	
1-15	West Texas	5.7	196.0	
1-21	Tucupido	5.1	11.5	
1-22	Tucupido	6.2	8.1	Inhibitor Plus pH Control (Ammonia)
1-29	Ruiz Mercedes	6.5	11.6	
1-30	Ruiz Mercedes	6.2	8.5	
2-4	Ruiz Mercedes	6.6	0.76	
2-6	Ruiz Mercedes	6.7	0.30	
2-13	Ruiz Mercedes	2.9	18.20	(Low pH)
2-14	Ruiz Mercedes	6.7	3.5	Raise pH to 8.0 + Inhibitor
3-12	Tucupido	8.5	0.0	
3-13	Tucupido	8.2	0.03	
3-14	Kuwait	8.6	0.20	
3-14	to 4-15	†8.2	†0.20	

* Kontrol.

† Average.

luted with a suitable hydrocarbon solvent, such as naphtha or kerosene, at a ratio of one part inhibitor to three parts solvent. Such dilution results in better distribution of the inhibitor, easier pumping and because small volumes of inhibitor are required, closer feed rate control. The inhibitor injection point should be as far away from the condensing equipment as possible. Usually a small nipple is welded within the first foot or so of the horizontal section of the vapor line. It should be placed on top of the vapor line and so located that the inhibitor does not flow back by gravity into the top of the tower.

The amount of inhibitor required for treatment is based upon the total overhead condensed hydrocarbon, i.e., a product-plus-reflux. The treating procedure is as follows:

Treating Procedure

1. For the first 7 days, treat at a rate of 1 gallon of inhibitor per 1000 barrels of gross overhead.
2. For the next 7 days, treat at a rate of $\frac{1}{2}$ gallon of inhibitor per 1000 barrels of gross overhead.
3. Thereafter, treat at a rate dependent on control



Figure 2—No. 2 unit heat exchanger in service 94 days before inhibitor was used.

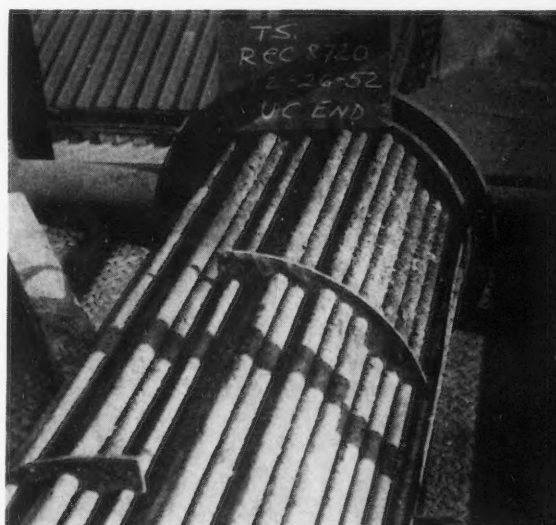


Figure 3—No. 2 unit heat exchanger tube bundle in service 117 days after inhibitor's use was started.

procedure, such as analysis of condensed water for metals content.

The pH of the overhead condensed water should be maintained at approximately 7.0.

Significance of pH Control

It is important that the pH of the condensed water be controlled, as the compounds are less effective at lower pH. Like all organic compounds containing basic nitrogen, these inhibitors will react with acids to form salts. These acid salts are water-soluble to the extent that their filming properties are sharply reduced. This change in solubility is exemplified by Figure 1, illustrating the distribution ratio between oil and water of such an inhibitor at various pH levels.

Normally, the control of pH is not a problem, because ammonia usually is used for partial corrosion prevention in most refineries. The use of both ammonia and inhibitor frequently will lead to a very definite reduction in corrosion. This may be shown by data collected from an East Coast refinery where condensed waters were analyzed for iron content. These data are illustrated in Table 1, Effect of pH Control.

It may be noted that in this system where pH adjustment by the use of ammonia was the only method of corrosion control used, iron content of the water was in the range of 50 ppm to 70 ppm, with an occasional very high value being obtained. Immediately following the start of inhibitor injection, the iron content increased rapidly for a few days, indicating the removal of corrosion products by the detergent action of the inhibitor which will be discussed later. When the inhibitor was in use and the pH was controlled to approximately 8.0, iron content averaged only 0.20 ppm, in the system under discussion.

Inhibitor Detergent Action

The deposition of corrosion products, such as iron sulfide, copper sulfide, etc. and salts formed as a result of pH control, such as ammonium chloride and ammonium sulfide, on heat exchange and condensing equipment is many times more often responsible for "shutdowns" than corrosion.

These salts, being polar, tend to deposit or bake onto the water-wetted metal tube surfaces. Through the use of the inhibitor, which forms a film over the surface, the metal becomes preferentially oil-wetted. Under these conditions, the salts no longer tend to deposit but are removed with the accumulator water draw-off.

An example of the detergent action of the inhibitor is illustrated by Figures 2 and 3, taken at a refinery which was processing desalted Mid-Continent crude. These heat exchanger bundles were in service in a crude-topping still handling 2800 barrels of crude daily, fed at a temperature of 700 F and flashed at 18 psi. The top-of-the-tower temperature was maintained in the 200 to 220 F range.

Results of Treatment

The best way to describe the effectiveness of these compounds as corrosion inhibitors is by citing examples of their use and performance. The following are typical:

Refinery A: In this refinery the overhead of a bubble tower crude unit was treated with the inhibitor. The vapors left the tower at 334 F, passed through three air-fin condensers in parallel and then through three after-coolers in parallel, the condensate being collected in an accumulator. Total gross hydrocarbon overhead amounted to 11,420 barrels per day, of which 6380 barrels was refluxed. The remainder went to product. The water draw-off was 640 lb./hr. The amount of inhibitor used was one gallon per shift or three gallons per day.

The following summary is quoted from the refinery operating report:

"Comparing the No. 1 Crude Unit run from June-Dec. 1951, when inhibitor was not used, with the run December 1951-August 1952, when inhibitor was used the following observations can be made:

1. The Dec. 1951-Aug. 1952 run was one of the longest on record.
2. Corrosion in the atmospheric overhead vapor line leaving the crude-to-vapor exchangers was materially reduced.



Figure 4—Outlet nozzle and baffles on channel end of debutanizer charge exchanger showing corrosion before application of inhibitor.

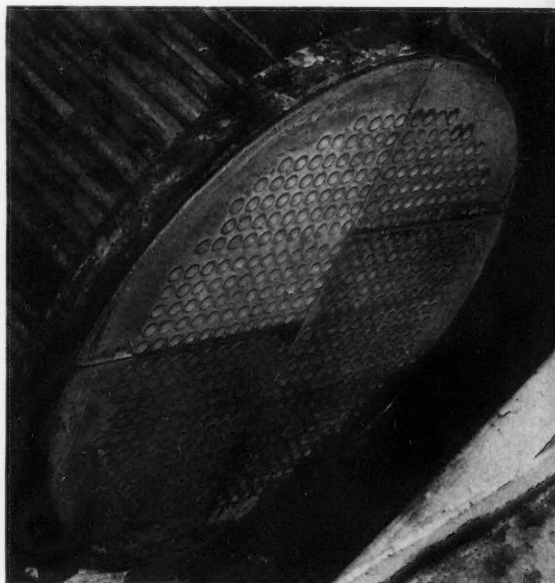


Figure 5—Tube sheet on channel end of debutanizer charge exchanger showing corrosion before application of inhibitor.

3. There was 80-90 percent less fouling on the vapor side of the vapor-to-crude exchanger with a consequent improvement of heat transfer rate.
4. The inhibitor was carried into the atmospheric tower with the reflux stream. As a result no tray cleaning was necessary for this turn-around.
5. Laboratory data clearly show that the inhibitor will slough accumulated fouling material.

It is recommended that the use of the inhibitor be extended to all points where fouling due to iron sulfide occurs in heat exchangers or towers."

Refinery B: The inhibitor was applied to the tube side of a debutanizer feed stream heat exchanger handling a catalytically cracked feed which was being heated to about 230 F at 200 psi, such condi-



Figure 6—No. 2 crude unit overhead condenser tube failure June 14, 1952.



Figure 7—No. 2 crude unit overhead condenser.



Figure 8—Crude unit overhead condenser X-281 after inhibitor injection.



Figure 9—Crude unit overhead condenser X-281 after inhibitor injection.

tions allowing the presence of liquid water. This water contained about 500 ppm chlorides, considerable polysulfide salts and finely-divided suspended iron sulfide. The pH of the water was 8.8.

When first placed on stream, the exchanger, with common steel tubes, failed after a 3-month period. It was necessary to retube the upper half of the

bundle. The next run lasted six weeks, when the upper half was again retubed on November 20, 1949. Figure 4 of the outlet nozzle and baffles on the channel end shows the extent of corrosion suffered.

On December 14, 1949, injection of inhibitor was started, at the rate of one gallon of inhibitor per 9000 barrels of throughput. No failure of the bundle has occurred to this date, some 47 months since start of treatment. Figure 5 indicates the condition of this bundle at the last "turn-around" inspection in April, 1953.

Refinery C: The No. 2 Crude Unit handles approximately 9000 barrels per day of desalted Mid-Continent crude. In the past, the overhead condensed accumulator water has been maintained to a pH of 7.0 to 7.5 by the use of ammonia for corrosion control.

This crude unit has been placed "on-stream" with all new equipment in March, 1950. In June, 1952, failure of the overhead condenser bundle occurred and the unit was "shut-down" for inspection and repairs. Figures 6 and 7, taken during this shut-down, illustrates the degree of corrosion which occurred to the tube bundle during this period.

At this shut-down in June, 1952, a new overhead condenser bundle was installed and the crude unit was again put into operation. From June, 1952, until January, 1953, the use of ammonia, as a means of corrosion control, was continued.

In January, 1953, injection of the inhibitor was started at a rate of one quart per 1000 barrels of gross overhead. Analysis of accumulator water for metals content has indicated that good corrosion protection has been achieved as judged by the reduction in metals content. In June, 1953, an inspection of the unit was made. The overhead condensing section and the tower were very clean; no fouling could be noted, which was not previously the case. Little, if any, corrosion could be noted, although the unit has not yet been treated long enough to evaluate this property fully. Figures 8 and 9 indicate the condition of the condenser tube bundle during the June, 1953, inspection.

Summary

These organic inhibitors have been used in a variety of applications. They have been proven effective in the prevention of hydrogen blistering found in catalytic cracking systems; corrosion in ethanalamine sweetening systems, in adsorbers and in other types of process equipment too numerous to mention. The widespread use of these organic inhibitors is due to several factors. These compounds are:

1. Effective corrosion inhibitors.
2. Excellent detergents.
3. Easy to use with simple equipment.
4. Very economical.

These properties, of course, mean a saving in operating and corrosion costs. Therefore, it is believed that in the future the use of organic inhibitors will become standard procedure in controlling corrosion in refineries. These organic inhibitors, offering a new tool for the refinery corrosion engineer, illustrate the progress of modern-day science in the ever-increasing fight to stop corrosion.



Discussions

Underground Corrosion Round Table. Selected from questions and replies at the session held at the NACE 10th Annual Conference, Kansas City, March 15-19, 1954:

Questions by James Robert Cowles, Tulsa, Oklahoma:

1. Can anyone offer observations on the effects of cathodic protection on well known corrosion of pipe as it emerges from soil or concrete (as in the case of pipes coming through basement wall)? 2. Discuss insulation of salt water gathering lines.

Discussion by David Hendrickson, Oakland, California:

The connection of concrete coated pipe with bituminous coated pipe can cause accelerated corrosion at the defects of the bituminous coating. The concrete coated pipe is cathodic to the exposed defects of the bituminous coated pipe. See *CORROSION*, June, 1952, Page 212.

Question by Sidney K. Gally, Southern California Gas Company, Los Angeles, California:

I have heard that alternating current superimposed on a magnesium galvanic anode may be rectified in such a manner as to reverse the direction of current flow between the anode and the pipe. Has anyone had any experience with this?

Question by Orville W. Zastrow, Chevy Chase, Maryland:

With reference to corrosion due to sulfate reducing bacteria or other organisms, are there specific measures applicable that would not be used against similar corrosion if the bacteria were absent?

Discussion by Kenneth Dudley Wahlquist, Dallas, Texas:

Described underground lead sheathed cables running through cast concrete walled manhole. Water stood in manhole over cables most of the time. Cables were drained of street railway stray current maintaining negative potentials, referred to lead slug, or 3-4 volts. Calcium deposit (no chemical analysis) 2 to 3 inches thick built up on exterior of cable. Manhole was drained of water. No apparent ill effect on cable under deposit. Concrete walls that were submerged could easily be scraped away with stick or other blunt object. No doubt that current passing through concrete had decomposing effect.

Question by Fred R. Blankenship, Jr., Southern Natural Gas Company, Birmingham, Alabama:

What is considered to be the maximum allowable

pipe-to-earth potential which may be maintained on coated pipe without danger of damage to the coating?

Question by Charles L. Mercer, Westfield, Texas:

Would it be possible for the various companies using the Cu So₄ half cell to write why some use the half cell over the pipe and others use the half cell remote from the pipe. What are the advantages and disadvantages of each method?

Discussion by Marshall E. Parker, Houston, Texas:

"Short-circuiting" of an insulated joint will almost never pass enough current to defeat the purpose of the joint; it may, however, bring about damage through "jumping." The "short-circuiting" of an insulated joint by the soil or water in which it lies, or by the fluid which it carries, will almost never pass enough current to effectively defeat the purpose of the joint. However, the passage of current around such a joint, by flow through the surrounding or contained medium, can cause damage to the section which lies at the higher potential, by simple anodic action. This can be avoided by a) coating the joint, or, better, installing it above ground; b) coating a length of pipe internally or externally, each side of the joint, which will both decrease the total current passed and increase the affected area by improving distribution; or, c) installing a resistance bond which will provide a measure of protection to the "unprotected" side of the joint. Another measure may be the installation of a small amount of drainage, as by a magnesium anode, on the unprotected side.

Cast iron pipe, with lead joints, suffered considerable damage from current by-passing the joints through low resistance soil. This could be avoided only by bonding every joint. A case was observed where severe graphitization had been inflicted on the ends of several successive joints of cast iron pipe by the attempt to place the line under cathodic protection without bonding the joints. In this particular case, the (cement) joints were non-conducting and the potentials imposed by the rectifier were sufficient to cause an appreciable current to flow through the low resistivity soil (about 200 ohm-cm). Similar effects have been observed even with leaded joints in which apparently the low melting point and low specific heat of the lead are such that the thin film of asphalt paint on the cast iron pipe is not melted and joint is obtained which is water-tight but also virtually insulating. The ends of the joints most distant from the drainage point showed definite cathodic scale for four successive joints, whereas the other ends were attacked at diminishing depths.

Questions by Harold C. Boone, Chicago, Illinois:

1. What are some satisfactory ways of coating in-

sulated flanges to prevent moisture from shorting them out? 2. In connection with gas service steel pipe feed from cast iron mains, what is the experience in the use of nylon bushings at the main?

Discussion by S. Clifford Jones, Corrosion Control Engineer, Cincinnati, Ohio:

Concerning use of anodic fittings in cast iron mains our company is now installing copper services with brass fittings N-C. The fittings and a short section of service are coated. Mr. Peabody of Ebasco Services said that thought should be given the use of fittings that would be cathodic to the mains, especially cast iron mains in distribution systems. A gentleman from California suggested that suppliers should provide such fittings. In fact, I felt he chided them for not having had them in the past.

The Cincinnati Gas & Electric Company has been using copper services to some extent since 1933. These services were installed with brass fittings and we have had no ill effect from their use.

Cathodic Protection in Florida Power and Light Company's Generating Plants by Joseph B. Prime, Jr. *Corrosion*, Vol. 10, No. 5, 165-168 (1954) May.

Question by Harrison G. Burbidge, Montreal, Canada:

Did you have any trouble with electrical connections to the anodes?

Reply by J. B. Prime, Jr.:

No trouble has been experienced with electrical connections to the anodes. All anodes are furnished with a 5-foot tail and the connection to this tail is made completely waterproof.

Question by Robert C. Mill, Westfield, New Jersey:

In the installation described, was it necessary to provide electrical bonding between the individual screen baskets?

Reply by J. B. Prime, Jr.:

On some traveling screens it was found necessary to provide electrical bonding between the individual screen baskets. We have found it necessary to check each installation for determining the use of bonds.

Questions by Rodney B. Teel, International Nickel Company, Inc., Wrightsville Beach, North Carolina:

1. Why do you use copper screen wire when the entire structure is under cathodic protection? 2. Have you run into any mechanical failures which may have been caused by hydrogen embrittlement of the steel structure as a result of maintaining such a high potential value (-1.2 v when actually all that is needed is $.86$ v vs CuSO_4)?

Replies by J. B. Prime, Jr.:

1. Copper screen wire was substituted for galva-

nized because under cathodic protection the corrosion products of the zinc forms a high resistance at the junction points of the wire and, therefore, insufficient protection currents are supplied.

2. At this date, no mechanical failures due to hydrogen embrittlement of the steel structure has resulted. (A potential of negative 1.2 volts to CuSO_4 was maintained for protection of the galvanized steel structures).

Industrial Applications of a Method for Measuring Small Amounts of Corrosion Without Removal of Corrosion Products by Andrew Dravnieks and Horace A. Cataldi. *Corrosion*, Vol. 10, No. 7, 224-230 (1954) July.

Question by Frank L. LaQue, The International Nickel Co., Inc., New York:

What advantage is there in using small specimens and tests of short duration?

Reply by Andrew Dravnieks:

The test method described in the paper cannot substitute for a full-scale corrosion experience in field applications just as is the case with any other laboratory procedure. This limitation should be realized, and we thank Mr. LaQue for stressing this point once more. The method is nothing more than a form of "electrical weighing." However, there are numerous occasions where a corrosion research group is called upon to develop urgently needed information on relatively corrosivity changes, relative corrosion resistances and similar items. In such cases, the only way out is to obtain the information by properly set experimentation. Specifically, in the non-electrolytes, many of the macrotopical effects disappear and the pitfalls of the sort outlined by Mr. LaQue are much less frequent. Under such conditions, the method has served satisfactorily and has provided answers in good agreement, even quantitatively, with the field ratings obtained concurrently or consecutively.

Aluminum Alloy Heat Exchangers in the Process Industries by W. W. Binger and Harry W. Fritts. *Corrosion*, Vol. 10, No. 12, 425-431 (1954) Dec.

Question by Bryant West Bradley, Shell Oil Company, New York:

We have used 3S aluminum heat exchanger bundles in a glycol-amine plant for three years. These units have been examined once each year and no significant corrosion has been observed to date. Three or four tubes in one exchanger did experience failure where the tubes had been dented while installing the bundle in the shell. These failures were thought due to erosion of the dent.

In view of this experience, it appears that aluminum might also be suitable for glycol-amine reboiler tubes. However, baffle cutting has been experienced on carbon steel and Croloy 5 tubes and probably would cause similar or possibly more severe failures of this type with aluminum. Do you have

any information on this subject beyond that reported by the Fluor Corporation and the work done by the major user of glycol-amine treaters in West Texas?

Reply by W. W. Binger and Harry W. Fritts:

We do not have any additional information at this time. Although baffle cutting often may be eliminated or appreciably reduced by design changes, we currently are evaluating the effect of alloy, temper, baffle width and surface coatings as they might affect the performance of aluminum heat exchanger tubes in services where baffle cutting has been troublesome.

Question by Gerard Sorrell, M. W. Kellogg Co., New York:

I questioned the suitability of aluminum in aqueous-amine units. While it is well known that aluminum performs excellently in glycol-amine units, the literature (Riesenfeld, Fluor Corp.) does not advocate aluminum for amine solutions containing more than 20 percent water.

Reply by W. W. Binger and Harry W. Fritts:

Aluminum tubes have been used in acid gas condensers and solution coolers in desulfurization units and to a limited extent for all the exchangers in carbon dioxide removal systems. Although aqueous-amine solutions as employed in commercial units can be corrosive to most commercial alloys, laboratory tests in model equipment have indicated that the corrosion of aluminum alloys can be controlled by additions to the amine solutions and also by proper choice of aluminum alloys.

Question by F. L. Whitney, Jr., Monsanto Chemical Co., St. Louis:

What is effect of velocity of polluted sea water on plain 3S and Alclad 3S?

Reply by W. W. Binger and Harry W. Fritts:

It is difficult to answer questions on the effect of velocity because our observations indicate that the nature of the flow (that is, turbulence, change in direction, etc.) is more significant than velocity as measured by volume of liquid divided by the cross-sectional area. We normally have been more concerned with the contaminants that have polluted the sea water. We believe that Alclad 3S would be a better choice than 3S for handling polluted sea water.

Comment by Hugh P. Godard, Aluminium Laboratories, Ltd., Kingston, Ont.:

As I recall, Binger made some remarks about the influence of water velocity on the corrosion of aluminum tubing. In this connection, I commented that in our work on the pitting corrosion of aluminum we had found that even slow velocities in the order of 8-10 feet per minute prevented the initiation of pitting in otherwise aggressive waters. Further, where pitting did occur, the rate of penetration was lessened. At high velocities—somewhere in the order of 20-30 feet per second, we believe that corrosion may be encountered due to impingement caused by turbulence at bends and fittings. In one case, we en-

countered such pitting at a velocity of 24 feet per second.

Questions by Frank C. Bunker, Pan American Refining Corp., Texas City, Texas:

1. Would the author comment more specifically on allowable chloride concentrations in cooling water?
2. What is comparative cost of Alclad 3S tubes relative to carbon steel tubes?
3. What is the effect of mercaptan vapors on aluminum tubes in the 700 degree F range?

Replies by W. W. Binger and Harry C. Fritts:

1. There is no specific "allowable" chloride concentration for cooling waters being handled by aluminum heat exchanger tubes. Service histories show cases where aluminum alloys have successfully handled sea water and even ammoniated salt brines.

Chlorides increase the conductivity of water and therefore may increase galvanic corrosion from dissimilar metal contacts, if they are present, or aggravate the effect of "heavy" metals which might be present in the water.

We use as a "rule of thumb" the principle that if the chloride concentration is above 50 ppm, Alclad 3S tubes are recommended rather than non-clad 3S and that aluminum tube sheets are preferable to mild steel.

2. The comparative price varies with size, however, in the common 3/4-inch and 1-inch by 16-gauge sizes, Alclad 3S tubes run about 20 to 25 percent less than seamless mild steel.

3. We have no information on the effect of mercaptan vapors on aluminum tubes at 700 degrees F. Aluminum tanks and piping are used for the room temperature handling of certain mercaptans. It should be noted that where aluminum tubes fall under the jurisdiction of the ASME Code, the maximum allowable metal temperature is 400 degrees F.

Questions by Andrew Dravnieks, Standard Oil Co. of Ind., Whiting, Ind.:

1. What is experience on influence of chlorides in oil streams on corrosion of heat exchanger tubes of aluminum, on the oil side?
2. What is known on corrosion resistance with respect to naphthenic acid?

Replies by W. W. Binger and Harry C. Fritts:

1. If this question is prompted by the possible use of aluminum tubes in crude still overhead condensers where chlorides form hydrochloric acid, our experience has been that aluminum tubes are not suitable unless the streams are neutralized by properly controlled ammonia injection equipment.

2. Aluminum equipment, including a column, condensers, evaporators, collectors and heating coils, has been used since 1935 for the distillation of crude naphthenic acid. Refined naphthenic acid also is shipped in aluminum alloy tank cars.

Question by Harold L. Smith, Kansas City, Mo.:

Have you had any experience with perchloroethylene

in aluminum stills, and does water content have any effect on rate of corrosion?

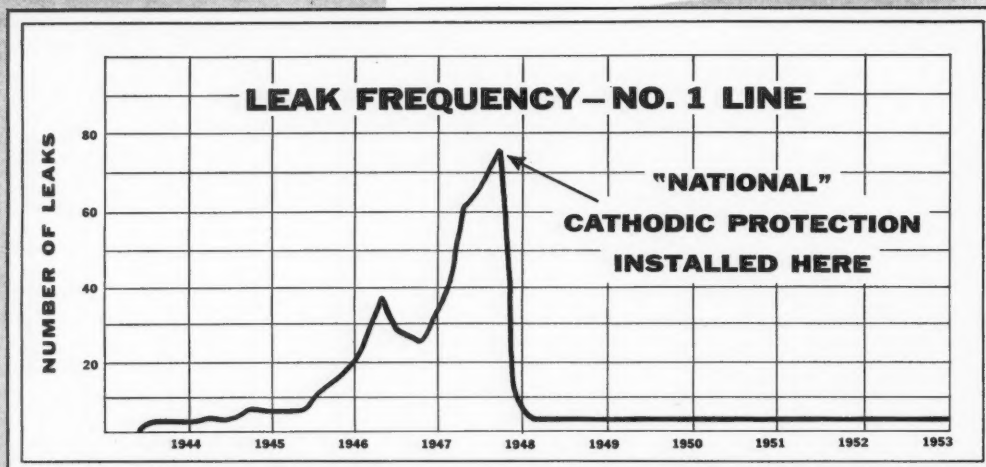
Reply by W. W. Binger and Harry C. Fritts:

Our experience indicates that dry perchloroethylene has no effect on aluminum alloys 3S or A54S. Many chlorinated hydrocarbons become reactive in the presence of moisture, particularly at elevated temperatures. We have not checked the effect of mois-

ture in perchloroethylene on aluminum.

An aluminum manufacturer in Germany, however, (Weiler, O. *Aluminium* [German] **28**, 441-2 [1952] Dec.) has built a complete aluminum alloy degreasing unit for use with perchloroethylene solvent. This unit consists of an elongated degreasing housing, an immersion tank, a still for the purification of perchloroethylene and storage tanks for the purified and contaminated solvent.

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NACE News

185 Attend Western Region's Fourth Conference

Marine and Waste Symposia Featured At Los Angeles

The Fourth Annual Western Regional Division Conference of the National Association of Corrosion Engineers held November 18-19 at Los Angeles had a registration of 185. Registrants participated in a technical program covering corrosion in marine environments and in waste disposal systems.

Social events included a fellowship hour and banquet at which W. H. Moore of Long Beach State College and Consultant to the United States Department of State for Far Eastern Affairs spoke on "The Challenge to America in Asia. A keynote address by Frank L. Whitney, Jr., Monsanto Chemical Company, vice-president of the National Association of Corrosion Engineers was titled "Industrial Liaison and the NACE."

Committee Session Held

An open meeting of Technical Committee T-4F on Material Selection for Corrosion Mitigation in the Utility Industry was held. R. R. Ashline, Department of Water and Power, Los Angeles, vice-president of the committee presided.

Harry J. Keeling, Southern Counties Gas Co., Los Angeles, program chairman, opened the meeting, introducing Mr. Whitney.

The Marine Corrosion Symposium, with Chairman L. L. Whiteneck, Long Beach Harbor Dept. presiding then followed taking the remainder of the day. Features on this program included a review of waterfront construction problems and possible remedies by C. M. Wakeman, Testing Engineer, Los Angeles Harbor Dept. and a discussion titled "Microbial Corrosion of Marine Structural Materials" by Claude E. Zobell, of Scripps Institute of Oceanography.

Factors influencing corrosion in sea water, with test results and corrosion rates of steels of varying compositions were presented by S. C. Frye, Bethlehem Steel Co., Bethlehem, Pa. under the title "Corrosion of Metal Structures in Marine Environments." Material Selection for Condenser Tubes was the topic selected by H. A. Todhunter of Los Angeles Dept. of Water and Power for a discussion of corrosion resistance, heat transfer and corrosion products formed on condenser tubes. His discussion covered water treatment also.

Lester Morris, Amercoat Corp., Los Angeles presented a paper titled "Selection of Coatings for Marine Structures" concerning marine paints and film deterioration processes.

Waste Disposal Symposium

C. G. Munger, Amercoat Corporation, Los Angeles, chairman of the Waste Disposal Symposium.

(Continued on Page 74)



SPEAKERS AND OFFICIALS at Western Region's November 18-19, 1954, meeting at Los Angeles were: (Top row, left to right) W. H. Moore, Long Beach State College, dinner speaker; Lester A. Morris, Amercoat Corp., Los Angeles; Ervin Spindel, Los Angeles Sewer Design Division; C. M. Wakeman, Los Angeles Harbor Dept.; Frank L. Whitney, Jr., Monsanto Chemical Company, St. Louis; (Bottom row, left) Claude E. Zobell, Scripps Institute of Oceanography. Some of the officials responsible for the meeting were: (Bottom row, starting second from left) L. L. Whiteneck, Long Beach Harbor Dept.; N. K. Senatoroff, Southern Counties Gas Co. and C. G. Munger, Amercoat Corp., co-chairmen of program committee and Harry J. Keeling, Southern Counties Gas Co., program chairman.

UCLA Course on Protective Coatings Held

Western Region Officers To Be Installed Jan. 26

Officers elected by Western Region will be installed at a joint Western Region—Los Angeles Section meeting January 26 as follows:

R. H. Kerr, Southern California Gas Company, Los Angeles, regional director. He takes office March 11, 1955.

R. S. Treseder, Shell Development Co., Emeryville, chairman; R. E. Hall, Union Oil Company, Brea, vice-chairman; E. F. Hensley, Dow Chemical Co., Pittsburg, Cal., secretary-treasurer.

Edmonton Section's Rules Approved by Region

It has been announced that the board of trustees of the Canadian Regional Division has approved rules and regulations of the Edmonton Section.

Upon receipt of this approval, the Edmonton Section became a fully recognized section of the Association.

1955 Conference Is Set

The Fifth Annual Western Regional Division Conference will be held in November, 1955 at San Francisco.

The Inter Society Corrosion Committee has representatives from more than 30 organizations.

A Short Course on Protective Coatings held November 15-17 by University of California at Los Angeles in cooperation with the Western Region of NACE had the following agenda:

November 15—Theory of Protective Coatings, Francis K. Wilson, Menlo Park, Cal.; Surface Preparation, Arno J. Liebman, Pitmar Centrifugal Machine Co., Pittsburgh; Testing, Evaluation and Specification, Ray M. Wainwright, University of Illinois, Urbana.

November 16—Asphaltic Coatings and Mastic by R. J. Schmidt, California Research Corp., San Francisco; Coal Tar Coatings by George B. McComb, Standard Pipe Protection Co., St. Louis; Ceramic Coatings, J. E. Hansen, Ferro Corp., Los Angeles; Protective Oil Coatings, R. W. Lewis, Shell Oil Company, Wood River, Ill.; Metallic Coatings, Bertram Smith, Metallizing Engineering Co., Inc., Los Angeles.

November 17—Plastics, K. L. Leeg, Lebec Chemical Corp., Paramount, Cal.; Paints, Leo Forth, The Sherwin-Williams Co., Los Angeles; Panel discussion by all speakers.

Registrants including speakers totaled 99, of whom 83 were from California and 16 from nine other states of the United States and one from Kuwait. Company affiliations included suppliers, public utilities, petroleum companies, fabricators and contractors, universities, governmental agencies and consulting engineers.



PERMIAN BASIN SECTION OFFICIALS are shown here with their special guest at the November 8 meeting in Odessa, Texas at the Lincoln Hotel. Left to right, back row they are: C. C. Michel, Cardinal Chemical, Inc., incoming second vice-chairman; Bob Warden, Shell Oil Co., outgoing second vice-chairman; John Watts, Humble Pipe Line Co., outgoing first vice-chairman and incoming chairman; John Knox, The Western Company, outgoing chairman; and A. A. Alberts, The Western Company, incoming secretary. Front row: Dorothy Thompson, Odessa College coed, chosen by the section as "Miss Oil Show of 1954," a special guest at the meeting; Fred Gipson, Continental Oil Co., incoming first vice-chairman; Jay Stafford, National Tank Co., outgoing secretary-treasurer; Harold Winston, Gulf Oil Corp., incoming treasurer and Tom Newell, Neo-Chem Laboratories, permanent trustee. The meeting was addressed by George Purdy, research chemist in charge of corrosion inhibition, Tret-O-Lite Corp., St. Louis. (Photo by Drill Bit Magazine.)

Detroit Section Members To Be in Corrosion Panel

A panel on corrosion will be composed of members of Detroit Section on February 14 on the opening day of an Industrial Ventilation Conference to be held at Kellogg Center on the campus of Michigan State College, East Lansing. The conference is sponsored by the Division of Occupational Health of the Michigan Department of Health, Continuing Education Service of Michigan State College and the School of Engineering of the college with the assistance of industry.

The panel, and the subjects each member will cover are as follows:

J. D. Guttenplan, Engineering Dept. Chrysler Corp., "Metals."

N. A. Kerstein, Research Dept., Detroit Edison Co., "Coatings."

L. W. Gleekman, Materials Engineer, Wyandotte Chemicals Corp., "Non-Metallic Materials."

E. V. Ivanso, vice-president, Detroit Testing Laboratory, Inc., chairman and moderator.

A version of this program also is scheduled for presentation at the January 6 meeting of Detroit Section at the Engineering Society of Detroit headquarters.

22 Attend Final 1954 Corpus Christi Meeting

Approximately 22 members and guests attended the final 1954 meeting of Corpus Christi Section of November 23. Dale Cole of the Tnemec Company spoke on free alkaline corrosion control on primers.

Fred Hodson was re-elected trustee for the section and it was announced that the February meeting will be in conjunction with the joint engineers' banquet during Engineers' Week.

Boiler Corrosion Panel Held by Portland Section

At the November 9 meeting of Portland Section at the Campbell Court Hotel, approximately 33 members and guests heard a panel discussion on Boiler Corrosion and Feedwater Treatment presented by Morris Rivers of the Crown-Zellerbach Corporation, Otto Hudrlik of the Flox Company, and Robert Baynham of the Dearborn Chemical Company.

The discussion was illustrated by photographs, drawings, coupons and pipe sections which showed typical corrosion failures.

The following officers were elected for 1955: Peter G. Behr, Portland Gas & Coke Company, chairman; Norman H. Burnett, Huntington Rubber Mills, vice-chairman; William R. Barber, Jr., Electric Steel Foundry Company, secretary-treasurer.

Oklahoma U. Short Course

At the November 15 meeting of the Central Oklahoma Section held in the YWCA Building, Oklahoma City, approximately 20 members and guests heard Dan Carpenter of the Sohio Petroleum Company, newly elected trustee, speak. It was also voted by the section that a contribution be made to further a second annual corrosion short course to be held at the University of Oklahoma during April of this year.

185 Attend—

(Continued From Page 73)

posals Symposium opened the second day's technical session by introducing Mark Brownstein of the Los Angeles Sewer Design Division who spoke on the Corrosion of Steel and Concrete in the Sewerage System. This subject was continued by Ervin Spindel, also of the division, who discussed Methods of Controlling Corrosion in the Sewerage System.

Factors involved in the disposal of petroleum wastes were covered in the presentation of Max M. Ellis of Union Oil Company titled "Corrosion in Oil Field Waste Water Systems." Oil field brine disposal problems and remedies were included.

Steel Water Line Corrosion

A round table discussion of the corrosion problems involved in the use of steel water pipes was held. The topic was pursued from coating manufacture, through applications of coatings and finally to field operation problems. Subjects and discussion leaders were:

Manufacture of Pipe Coatings by John I. MacManus, Barrett Division, Allied Chemical & Dye Corp.

Coal Tar Enamel Coatings for Steel Water Pipe by Walter H. Cates, Consolidated Western Steel Company.

Concrete-Mortar Coatings for Water Pipe by L. W. Irwin, American Pipe and Construction Company.

Application Methods Used in Coating Pipelines by C. O. Porter, Pacific Pipeline Construction Company.

Mastic Coatings and Their Properties by Austin S. Joy of Pipe Linings, Inc.

Experiences in Water Supply by R. E. Hemborg, Los Angeles Department of Water & Power.

A question and answer session ended the discussion.

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Fretting Corrosion Is Ohio Valley Topic

At the November 18 meeting of Ohio Valley Section, approximately 35 members and guests heard F. W. Fink of the Battelle Memorial Institute speak on the subject "Fretting Corrosion." The meeting was held in the Conference Room of the Reynolds Metals Company.

Officers were elected for 1955 as follows: Lewis P. Aker, Louisville Gas & Electric Company, chairman; Thomas E. Brady, Western Kentucky Gas Company, vice-chairman; Richard F. Hafer, Reynolds Metals Company, secretary-treasurer.

It was reported that the Ohio Valley Section had been elected to the Louisville Engineering and Scientific Society's Council.

At the January 20 meeting Kenneth Tator of Coraopolis, Pennsylvania will speak on Maintenance Painting and Paint Testing. On February 23 at a joint meeting with the American Institute of Electrical Engineers, V. B. Pike of Bell Telephone Laboratories will speak. It was announced also that no meeting will be held in March but plans are underway for meetings to be held in April and in the fall of 1955.

Man Made Refractories Discussed at Beaumont

Roy W. Brown of The Corborundum Co., Houston spoke to 20 members and 14 guests of Sabine-Neches Section December 2 on Refractories Utilizing Man-Made Materials. The meeting was held at Little Mexico Restaurant, Beaumont, Texas.

Mr. Brown discussed materials used to make super-refractories in the electric furnace and how refractories are made as well as their characteristics and uses. Color slides and a sound motion picture "Exploration With the High Temperature Microscope" were shown. A question and answer period followed.

Next section meeting will be January 27.

Seven Regional Meetings Held by NACE in 1954

Seven meetings of NACE Regions were held during 1954. Western and Southeast Regions each held two and Northeast, South Central and Canadian one each.

Largest of the meetings was the annual South Central Region meeting at Dallas with 555 registered.

Nine New NACE Sections Organized During 1954

Nine new sections were organized in the National Association of Corrosion Engineers during 1954. Of these the Northeast and Southeast Regions accounted for three each; Western Region for two and South Central Region for one. There were 47 sections at the end compared to 38 at the beginning of the year.

Sections organized were: Northeast Region—Genesee Valley, Lehigh Valley, Schenectady-Albany-Troy; Southeast Region—East Tennessee, Ohio Valley and Tidewater; South Central—Alamo; Western—Central Arizona and Portland.

Talk by Friend Scheduled By Philadelphia Section

The last 1954 meeting of the Philadelphia section was scheduled to be held on December 10 at the Poor Richard Club in Philadelphia.

Some Corrosion and Material Problems in the Chemical Industry was the topic prepared for presentation by W. Z. Friend of the International Nickel Co.

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Cathodic Protection Is Sudrabin's Chicago Topic

L. P. Sudrabin of Electro Rust-Proofing Corporation, spoke to approximately 80 members and guests of the Chicago Section November 16 on Criteria Used in Cathodic Protection. Mr. Sudrabin said that the corrosion engineer must rely on indirect electrical measurements to diagnose his problems. He pointed out that local cell activity is much more prevalent in practice than is recognized in corrosion literature.

A series of demonstrations in a model cell showed that electrical effects of various dissimilar materials as well as the importance of the position of the reference electrode in determining potential. The reactions occurring in tubercle corrosion before and during cathodic protection were described and the work was then related to the protection of pipe lines and tanks of ocean tank ships. In the latter the use of plaster casts of corrosion pits was demonstrated as a useful and novel method of following corrosion attack. In respect to pipe lines Mr. Sudrabin recommended the use of a good protective coating in all cases in order to simplify the cathodic protection of a system.

deBethune on Program of Greater Boston Section

Andre J. deBethune was scheduled to speak on Corrosion and Electrochemistry at the December 14 meeting of the Greater Boston Section to be held at the Hotel Beaconsfield in Brookline, Massachusetts.

Cleveland Features Process Equipment Corrosion Discussion

At Cleveland Section's November 15 meeting, approximately 30 members and guests heard a panel discussion headed by Tom Howald of the Chase Brass & Copper Company on Corrosion Prevention in Process Equipment. Other members of the panel were: Carl E. Heil, Heil Process Equipment Corp., who spoke on Selection of Non-Metallic Materials in Process Plants; Everett Gosnell, Gusett Boiler & Welding Company, who spoke on Selection of Metals and Alloys for Process Equipment and Harry Hosford, Harco Corp., who spoke on Cathodic Protection of Equipment.

The meeting was held jointly with the Process Industries Division of the Cleveland Engineering Society and developed information valuable to designers, fabricators and corrosion engineers because speakers were experienced in their respective fields.

Next regularly scheduled meeting will be on January 11, 1955.

Fluorocarbon Symposium

"Fluorocarbons, Modern Weapons of the Corrosion Age," was the topic of a symposium presented at the November 18 meeting of Detroit Section. Properties, applications and uses of Kel-F and Teflon were discussed by approximately 50 members.

W. B. Happoldt of the Polychemicals Dept. E. I. duPont de Nemours & Co., Ltd., and L. J. FitzHarris of the Kellogg Company were speakers.

Kansas City Section Hears Wrenn's Talk On Holiday Detectors

At the November 22 meeting of Kansas City Section, George Wrenn of the Pipeline Inspection Company, Kansas City, Missouri, presented a talk on Operation of Holiday Detectors for Pipe Coating Inspection. The main points of the talk were demonstrated by Mr. Wrenn with equipment which he provided. Various improvements in holiday detector design were demonstrated and some of the causes of holidays in enamel coating were explained.

Election of officers for the coming year was held at this meeting and various plans discussed for improving the section organization. New officers for 1955 will be: R. A. Kelley, Minnesota Mining and Manufacturing Company, chairman; J. C. Berringer, Panhandle Eastern Pipe Line Company, vice-chairman; A. L. Kimmel, Thiemec Company, Inc., secretary-treasurer.

Genesee Valley Section, ASM Hear Whitney On Materials Selection

Approximately 50 persons attended the joint meeting of the Genesee Valley Section and the Rochester Chapter of the American Society for Metals November 8.

F. L. Whitney, Jr., of Monsanto Chemical Company spoke on factors in the selection of corrosion-resistant materials. With charts and slides, he illustrated stress corrosion, cell action, erosion and fretting corrosion. Mr. Whitney also gave some interesting examples of how poor design or changes in the chemical process conditions can cause good materials to fail prematurely.

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SHORT COURSE CALENDAR

1955

Jan. 20-21—Houston Section Short Course.
Jan. 24-28—UCLA, Los Angeles, Cal.
Feb. 2-4—University of Toronto, Hart House Theater, Toronto.

Feb. 16-18—Tulsa Section, Sixth Annual Short Course, Mayo Hotel, Tulsa, Okla.

Mar. 1-4—University of Tennessee, Knoxville.

April 5-7—University of Oklahoma. Second Annual Corrosion Control Short Course, Norman, Okla.

April—University of British Columbia, Vancouver.

Fall—Washington University, St. Louis, Missouri.

Pittsburgh Section

Pittsburgh Section met for a regular monthly meeting at the Mellon Institute in Pittsburgh on December 2 1954. Approximately 60 members and their guests heard Jerome M. Bialosky of the Koppers Company Experimental Station, Verona, Pennsylvania speak on Corrosion in the Chemical Industry. Color slides were shown depicting corrosion of various alloys and the corrective measures taken.

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NACE MEETINGS CALENDAR

- Jan.**
- 3 North Texas Section. Installation of officers.
 - 6 Pittsburgh Section. J. Teres, Air Research and Development Command, will speak on corrosion problems in military aircraft.
 - 10 Permian Basin Section. Panel discussion on casing corrosion.
 - 12 Niagara Frontier Section. Discussion—Metallurgical Approach to the Solution of Corrosion Problems in the Process Industries by Walter E. Luce, Duriron Company, Inc., Dayton, Ohio.
 - 13 Kanawha Valley. Huntington, W. Va. Topic to be announced.
 - 17 Lehigh Valley. Corrosion Inhibitors in Boiler Systems and Cooling Applications by R. H. Hayman, W. H. & L. D. Betz. Keystone Trail Inn, 19th and Albright, Allentown, Pa. Dinner 6:30 pm, meeting 8 pm.
 - 18 Chicago Section. H. V. Nyland, Sinclair Research Laboratories, will present the applications of economic analysis to refining corrosion problems.
 - 18 Montreal Section. Discussion of electrolysis.
 - 20 Ohio Valley Section. Kenneth Tator, Coraopolis, Pa., "Maintenance Painting and Paint Testing."
 - 24 New Orleans-Baton Rouge Section. Corrosion Inhibitors and Inspection Methods.
 - 26 Metropolitan New York Section. The Chemists' Club.
 - 26 Sabine-Neches Section. Ladies night and installation of officers.
- Feb.**
- 2 Southern New England. Topic to be announced.
 - 3 Pittsburgh Section. Materials Engineering in the Process Industry by John L. McPherson, Materials Engineer, the Blaw-Knox Company, Pittsburgh.
 - 7 North Texas Section. Tentative speaker, Merrill Scheil, A. O. Smith Corp. Milwaukee.
 - 11 Philadelphia Section. Topic to be announced. Poor Richard Club, Philadelphia. Dinner 6:30 pm, meeting 8 pm.
 - 16 Genesee Valley. Joint meeting with Rochester Chapter, AIChE. Plastics for Corrosion Resistant Applications, by Raymond B. Seymour, Atlas Mineral Products Co.
 - 16 Greater Boston Section. Case History of Corrosion by F. L. Whitney, Jr., Monsanto Chemical Co. Hotel Beaconsfield, Brookline. Dinner 6:30 pm.
 - 21 Lehigh Valley. Metallizing for Corrosion Resistance, Walter Meyer, St. Louis Metallizing Co. Keystone Trail Inn, same details as Jan. 17 meeting.
 - 22 Montreal Section. Cathodic protection.
 - 23 Niagara Frontier. Field of chemistry.
 - 23 Ohio Valley Section. Joint meeting with AIEE. V. B. Pike, Bell Telephone Laboratories will speak.
 - 28 New Orleans-Baton Rouge Section. Internal Plastic Coatings for Tubing.

Corrosion Fundamentals To Be Stressed at March Conference in Knoxville

The University of Tennessee Corrosion Conference scheduled March 1-3 will be devoted to fundamentals for the most part, according to information from Anton deS. Brasunas, chairman. He also announced that the March 4 Oak Ridge tour originally announced has been cancelled.

The program tentative is as follows:

March 1

Registration and films on corrosion costs and heat treating fundamentals.
Introduction to Corrosion, A. deS. Brasunas, University of Tennessee.
Atmospheric Corrosion, H. R. Copson, International Nickel Co.
Coatings for Atmospheric Corrosion Protection, speaker to be named.
Corrosion at High Temperatures by W. O. Binder, Union Carbide and Carbon Company Research Laboratory.
Catastrophic Corrosion by Howard Liebhaufsky, General Electric Research Laboratory.

March 2

Liquid Metal Corrosion, speaker to be named.
Molten Salt Corrosion, speaker to be named.
Corrosion Problems in Power Plants, K. H. Logan, Cast Iron Pipe Research Association.
Unusual Practical Problems in Pipeline Corrosion by H. C. Van Nieuhuys, Southeastern Pipe Line Co.
Use of Plastics and Plastic Liners for Corrosion Protection, R. B. Seymour, Atlas Mineral Products Co.
Influence of Mechanical Factors on Corrosion, J. J. Harwood, Office of Naval Research.
Principles of Cathodic Protection, Milton Stearn, Union Carbide and Carbon Research Laboratory.
Banquet—A. B. Campbell, NACE executive secretary, principal speaker.

March 3

Corrosion by Sea Water, T. P. May, International Nickel Co., Inc.
Corrosion by Chemical Solutions, Frederick Fink, Battelle Memorial Institute.
Corrosion Failures in Chemical Industries, speaker to be named.
Passivation of Stainless Steels, N. A. Neilson, duPont Engineering, Research Laboratories.
Nature of Metals and Alloys, E. E. Stansbury, University of Tennessee.
General questions on corrosion fundamentals, panel of speakers.
Four simultaneous round tables on corrosion control practice on atmospheric corrosion, chairman to be named; high temperature corrosion, W. O. Binder, chairman; corrosion by chemical solutions, chairman to be named and underground corrosion, K. H. Logan, chairman.

Members of NACE may run a Positions Wanted classified advertisement annually in two consecutive issues of CORROSION without charge.

Extra copies of CORROSION can be bought from NACE, 1061 M & M Bldg., Houston.

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57 Firms Contract for Exhibit Space At Eleventh Annual Corrosion Show

O. B. Ellis Will Address Houston Section January 11



O. B. Ellis

O. B. Ellis, Senior Research Engineer at Armco Steel Corp., will be the principal speaker at the January 11 meeting of Houston Section. Mr. Ellis will talk on use of metallic coatings in combating atmospheric corrosion. The meeting will be held in Kelley's Dining Room upstairs.

Southwestern Ohio Plans Four Meetings During 1955

Dinner meetings of Southwestern Ohio Section are scheduled for January 25, February 22, March 29 and April 26 during 1955.

The January meeting will be held at Shuller's Restaurant in Cincinnati with dinner at 7 pm, and meeting at 8 pm. S. Clifford Jones will speak on Underground Corrosion and Sol Gleser will speak on Underwater Corrosion of Ferrous Materials. There will be a round table discussion with Robert Rommell as moderator.

The February meeting also will be held at Shuller's Restaurant with V. B. Pike of Bell Telephone Laboratories, Murray Hill, New Jersey, as speaker on the subject of "The Organization of Work of the American Research Committee on Grounding."

The March meeting will have S. C. Lawson of Ampco Metal, Inc. as speaker on the Corrosion Resistance of Non-Ferrous Alloys.

The April meeting will feature F. L. Whitney, Jr., vice-president of NACE as guest speaker.

Schenectady-Albany-Troy Section Hears Maitland

At the November 16 meeting of the Schenectady-Albany-Troy Section held in the Aurania Club in Albany, New York, approximately 25 members and guests heard T. J. Maitland of American Telephone & Telegraph Company present a paper on Engineering of Corrosion Protection for Underground Structures. The November 16 meeting was the section's first to be held in Albany. All previous meetings had been held in Schenectady.

It was announced that the following officers have been elected by letter ballot to serve during 1955: Edward L. Simons, General Electric Company, Research Lab., Box 1088, Schenectady, New York, chairman; John F. Klim, New York Telephone Company, 158 State Street, Albany, New York, vice-chairman; George V. Browning, General Electric Co. Turbine Division, Schenectady, New York, secretary-treasurer.

Contracts for space in the Eleventh Annual NACE Corrosion Exhibition have been signed by 57 firms through December 15. The exhibition will be held in the Palmer House, Chicago, concurrently with the Eleventh Annual NACE Conference March 7-11.

Names of firms whose contracts have been received are:

Aluminum Company of America
Amercoat Corporation
American-Marietta Company
Ampco Metal, Inc.
Anderson-Prichard Company
Apex Smelting Company
Aquaness Corporation
Bart Manufacturing Company
Barrett Division
(Allied Chemical & Dye Corporation)
A. E. Betzel Engineer Company
Brance-Kracy Company
A. M. Byers
Carboline Company
Cathodic Protection Service
The Chemical Corporation
Clementina, Ltd.
Continental Can Company
The Crane Company
Dampney Company
Dearborn Chemical Company
Dow Magnesium Department
(Dow Chemical)
Dresser Manufacturing Company
Duriron Company, Inc.
Electro-Rust-Proofing Corporation
Federated Metals Division
(American Smelting & Refining Company)
Goodall Electric Manufacturing Company
Haveg Corporation
Hercules Powder Company
Hill, Hubbell Division
(General Paint Corporation)
Insulmastic Corporation of America
International Nickel Company
Johns-Manville Sales Corporation
Knapp Mills, Inc.
Koppers Company, Inc.
Lebanon Steel Foundry
Lithco Corporation
Midwestern Engine and Equipment Company
New Jersey Zinc Company
Philip Carey Manufacturing Company
Pittsburgh Coke and Chemical Corporation
Reilly Tar and Chemical Corp.
Royston Laboratories
Rust-Oleum Corporation
Saran Lined Pipe Department
(Dow Chemical Corporation)
Shell Oil Company
Socony Paint Products Company
Standard Magnesium Corporation
D. E. Stearns Company
Spee-Flo Manufacturing Company
The Tapecoat Company
Texstream Corporation
Tretolite Company
Union Carbide & Carbon Corporation
United Chromium
United States Rubber Company
U. S. Stoneware
T. D. Williamson

All papers presented at annual meetings of NACE, except those not approved by the association's editorial review committee and CORROSION's editor, are published in CORROSION.

TECHNICAL REPORTS

Remittances must accompany all orders for literature the aggregate cost of which is less than \$5. Orders of value greater than \$5 will be invoiced if requested. Send orders to National Association of Corrosion Engineers, 1061 M & M Bldg., Houston, Texas.

Add 65c per package to the prices given below for Book Post Registry to all addresses outside the United States, Canada and Mexico.

- TP-1 Report on Field Testing of 32 Alloys in the Flow Streams of Seven Condensate Wells (Pub. 50-3) NACE members, \$8; Non-members, \$10 per copy.
- T-1A Survey of Corrosion Control in California Pumping Wells. A Report of T-1A on Corrosion in Oil and Gas Well Equipment, Los Angeles Area. Pub. 54-7. Per copy, \$5.00.
- T-1G Sulfide Corrosion Cracking of Oil Production Equipment. A Report of Technical Unit Committee T-1G on Sulfide Stress Corrosion Cracking. Pub. 54-5. \$5.00 Per Copy.
- TP-2 First Interim Report on Galvanic Anode Tests. (Pub. 50-2) NACE members, \$3; Non-members, \$5 per copy.
- T-2C Some Observations of Cathodic Protection Potential Criteria in Localized Pitting. A Report of T-2C on Minimum Current Requirements for Cathodic Protection. Pub. 54-2. Per copy \$5.00.
- TP-3 First Interim Report on Ground Anode Tests. (Pub. 50-1) NACE members, \$3; Non-members, \$5 per copy.
- T-4B-3 Tests and Surveys for Lead Sheathed Cables in the Utilities Industry. Second Interim Report of Technical Unit Committee T-4B on Corrosion of Cable Sheaths. Publication 54-6. Per Copy \$5.00.
- T-4B-4 Pipe-Type Cable Corrosion Protection Practices in the Utilities Industry. First Interim Report of Technical Unit Committee T-4B on Corrosion of Cable Sheaths. Publication 54-3. Per Copy \$5.00.
- TP-1D Sour Oil Well Corrosion. Corrosion August, 1952, issue. NACE members, \$5.00; Non-members \$1 per copy.
- TP-1G Field Experience With Cracking of High Strength Steel in Sour Gas and Oil Wells. (Included in Symposium on Sulfide Stress Corrosion. (Pub. 52-3) \$1 per copy. 5 or more copies to one address, \$50 per copy.
- TP-5A Materials of Construction for Handling Sulfuric Acid. Corrosion, August, 1951, issue. NACE members, \$5.00; Non-members, \$1 per copy.
- TP-5C Stress Corrosion Cracking in Alkaline Solutions. (Pub. 51-3) Per Copy, \$5.00.
- T-6A Application Techniques, Physical Characteristics and Corrosion Resistance of Polyvinyl Chlor-Acetates. A Report of Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion. Publication 54-4. Per Copy, \$5.00.
- TP-6G First Interim Report on Recommended Practices for Surface Preparation of Steel. (Pub. 50-5) Per copy, \$5.00.
- TP-6G Second Interim Report on Surface Preparation of Steels for Organic and Other Coatings. (Pub. 53-1) Per copy, \$1; five or more copies to one address, per copy \$5.00.
- TP-12 Report on Electrical Grounding Practices. Per copy \$5.00.
- TP-19 Corrosive Effects of Deicing Salts—A Progress Report by Technical Practices Committee 19. Corrosion, January, 1954, issue. NACE members \$5.00; Non-members \$1 per copy.

REPRINTS

of articles published in CORROSION

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Cathodic Protection and Pipe Lines

- Mitigation of Corrosion on City Gas Distribution Systems by A. D. Simpson, Jr. .50
Final Report—Effect of Exposure to Soils on the Properties of Asbestos-Cement Pipe by Melvin Romanoff and Irving A. Denison .50

Paints and Coatings

- Gasoline Resistant Tank Coatings by W. W. Cranmer .50
Tests, Properties of Corrosion Preventive Lubricants for Lead Sheathed Cables in Underground Ducts—A Discussion by Howard S. Phelps and Frank Kahn .50

Petroleum Production & Storage

- Corrosion in Condensate and in High Pressure Sweet Oil Wells by R. C. Buchan .50
A Promising Spray-Applied Inhibitor of Internal Corrosion of Oil Ship Tanks by J. D. Sudbury, D. A. Shock and F. W. Mann .50
Symposium on Internal Corrosion of Tankers. Part 3—Corrosion Control in Practice by A. B. Kurz .50
Bacterial Corrosion of Offshore Structures by J. A. Caldwell and M. L. Lytle .50
Corrosion Control in Gas Lift Wells. II Evaluation of Inhibitors. By D. A. Shock and J. D. Sudbury .50
Internal Corrosion in Domestic Fuel Oil Tanks by R. Wieland and R. S. Treseder .50

Economics

- The Cost of Corrosion to the United States by H. H. Uhlig .50
Relation of Corrosion to Business Costs by Aaron Wachter .50

Inhibitors

- Prevention of Corrosion in Cooling Water by R. C. Ulmer and J. W. Wood .50
Dicyclohexylammonium Nitrite, a Volatile Corrosion Inhibitor for Corrosion Preventive Packaging by A. Wachter, T. Skei and N. Stillman .50

Miscellaneous

- Resistance of Aluminum Alloys to Weathering by C. J. Walton, D. O. Sprowls and J. A. Nock, Jr., and Resistance of Aluminum Alloys to Contaminated Atmospheres by W. W. Binger, R. H. Wagner and R. H. Brown .50
Interpretation and Significance of Potentials of Metals in Aqueous Solutions by Morris Cohen .50
Effect of Heat Treatment and Related Factors on the Corrosion Resistance and Mechanical Properties of the Straight-Chromium Stainless Steels by F. K. Bloom .50
Statistics—A Useful Tool for the Examination of Corrosion Data by Chas. F. Lewis .50
Laboratory Studies on the Pitting of Aluminum in Aggressive Waters by T. W. Wright and Hugh P. Godard .50
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Corrosion Control by Magic—It's Wonderful by H. H. Uhlig .50

Program for Houston's Fundamentals of Pipeline Corrosion Short Course Given

The Short Course on Fundamentals of Pipe Line Corrosion sponsored by the Houston Section on the University of Houston campus January 20-21 will be presented by instructors who are noted for years of experience on the actual application and maintenance of cathodic protection and corrosion control, Charles L. Woody, general chairman of the course, said.

Following is the tentative short course program:

Thursday, January 20

- Morning Session: Chairman, W. A. Wood, Jr., Products Research Service, Inc.
9-9:10—Welcome, Purpose of Short Course, Costs of Corrosion by E. Clyde McGraw, vice president in charge of operations, Transcontinental Gas Pipe Line Co.
9:10-10—Why Do Pipe Lines Corrode Externally? by M. A. Riordan, Rio Engineering Co.
10-10:50—External Coatings for Pipe Lines by L. G. Sharpe, Napco Paint & Varnish Works.
11-11:50—Fundamentals of Cathodic Protection by Marshall Parker, Cormit Engineering Co.
Afternoon Session: Chairman, J. A. Holway, Houston Pipe Line Co.
1:10-2—Why Do Pipe Lines Corrode Internally and How to Control Internal Corrosion? by R. A. Brannon, Humble Pipe Line Co.
2-2:50—Design, Construction and Maintenance Planning for the Prevention of Corrosion of Pipelines by O. W. Wade, Transcontinental Gas Pipe Line Corp.
3-3:50—What to Look For and How to Report It by Marion Frank, Tennessee Gas Transmission Co.
3:50-4:40—Case Histories of Pipe Line Corrosion by Lyle R. Sheppard, Shell Pipe Line Corp.

Friday, January 21

- 9-9:10—Includes announcements, assignment of groups and group leaders.
9:10-12—Laboratory demonstrations of pipe line corrosion control methods.
1:10-2:30—Group discussions, with group leaders of main points of demonstrations and individual problems and experiences.
2:40-4—Moderator, C. L. Woody United Gas Corp. Round table discussion for complete assembly with summary, opinions, special problems brought up in group discussions, plans or desires for future course.
Tentatively named group leaders were: Gordon Doremus, Cathodic Protection Service; A. L. Stegner, Tennessee Gas Transmission Co.; Wayne Johnson, Corrosion Rectifying Co.; Wayne Broyles, Brance-Kracy Co., Inc.; Walter Noser, Humble Pipeline Co.; Paul Miller, Texas Pipe Line Co.; A. T. Surber, Trunkline Gas Co.; Howard G. Gumm, Industrial Gas Supply Corp.; J. H. McBrien, T. D. Williamson, Inc., all of Houston.

Classes are scheduled to start promptly at 9 am January 20. Cost of course is \$10. Facilities are available for registration from 7:30 am on January 20 in the

TV Lounge at Oberholtzer Hall on the university campus. Early registrations may be made by letter with checks or money orders made payable to Houston Short Course and mailed to Loyd Nelson, Shell Pipe Line Corp., P. O. Box 2648, Houston.

Wahlquist to Address Shreveport Section Jan. 18

K. D. Wahlquist of the Southern Union Gas Company, Dallas, will speak at the January 18 meeting of Shreveport Section to be held at Caddo Hotel. Mr. Wahlquist will speak on experience with cathodic protection of buried pipe lines. His talk will be illustrated with slides.

UCLA Short Course Set

A corrosion short course will be held by the University of California at Los Angeles during the week of January 24.

BOOK REVIEW

Standards and Typical Specifications for Deaerators and Deaerating Heaters. Third revised edition. 11 pages. 8½ x 11 inches, paper, 1953. Heat Exchange Institute, 122 E. 42nd St., New York 17, N. Y. \$1.00.

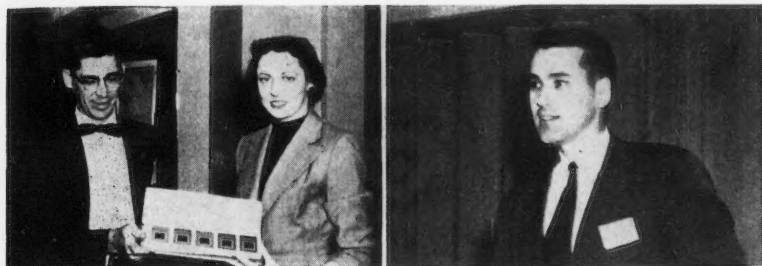
Object of the book is to help the purchaser of deaerators and deaerating heaters by defining terms and establishing standards of capacity, performance and construction. Material has been revised and rearranged. New table gives storage in minutes and cubic feet for tabulated capacity from 10,000 lb./hour to 1,600,000 lb./hour. Tables of shell and head thicknesses has been revised and expanded, as has the table on accessories election and standard opening sizes. The book contains the chart showing flow through valves in pounds per hour and tables giving temperature-pressure conversion from 140 degrees F to 212 degrees F and pressure temperature conversion from zero to 125 lb./sq. in. gauge. Typical specifications have been revised and brought up-to-date.

Low Temperature Test Methods and Standards for Containers—A Symposium. 6 x 9 inches, 126 pages, paper. September 1954. Published by Advisory Board on Quartermaster Research and Development, Committee on Packing, Packaging and Preservation, National Academy of Sciences—National Research Council, Washington. Copies available from Quartermaster Food and Container Institute for the Armed Forces, 1819 West Pershing Road, Chicago 9, Illinois. Free.

The books, replete with tables, charts and photographs, contains reports of tests and discussions on such subjects as water vapor permeability of sheet materials, background of use of multiwall bags by the armed forces, testing multiwall bags at low temperatures, toughness and gas transfer characteristics of plastic films at low temperatures and low-temperature degradation of flexible barrier materials.



OFFICERS OF NORTH TEXAS SECTION are shown here at the December 6 meeting, left to right: J. Gordon Meek, Metal Goods Corp., outgoing chairman; Paul C. Fleming, Gulf Oil Corp., Ft. Worth, chairman; E. H. Muehlhause, Lone Star Gas Co., Dallas, vice-chairman; Ken W. Robbins, Otis Pressure Controls, Inc., Dallas, secretary-treasurer.



NORTH TEXAS SECTION'S December 6 meeting saw (left) Miss Norma Lynch, Metal Goods Corp., receiving a gift from the section for doing the section's secretarial work during 1954. J. Gordon Meek, outgoing chairman, is making the presentation. Right is F. J. Radd, Senior Research Metallurgist, Continental Oil Company, Ponca City, Okla., and chairman of T-1F on Metallurgy, guest speaker at the meeting.

F. J. Radd Addresses North Texas Section on Petroleum Metallurgy

A dinner meeting of North Texas Section was held Monday, December 6 at the Plaza Hotel, Dallas, attended by 35 members and guests, who heard F. J. Radd, chairman of T-1F and Senior Research Metallurgist, Production Research Division, Development and Research Department, Continental Oil Company, speak on the subject of Petroleum Metallurgy.

His talk involved a description of the sources of corroding currents in sucker rods, tubing, casing, pipelines and ships. Of particular note was the effect of steel microstructure upon the corrosion resistance in common oil and gas production environments. A laboratory evaluation and comparison of the detailed electrode reactions of steels in hydrogen sulfide brines and in carbon dioxide brines was presented. The effects of steel microstructures upon brittle failure mechanisms for low temperature service, as in petrochemical manufacturing, were noted.

Whitney to Talk About Design Factors at Detroit

"Mechanism of Corrosion Related to the Design of Equipment," is the scheduled topic for discussion by Frank L. Whitney, Jr., Monsanto Chemical Co., St. Louis and vice-president of the National Association of Corrosion Engineers at Detroit February 24. He will address a joint meeting of the Detroit Section and The Electrochemical Society.

San Francisco Bay Section Hears Dancy

A meeting of San Francisco Bay Area Section was held November 17 at Oakland Willows Restaurant, Oakland, Cal. attended by 28 members and guests. Emmitt Dancy spoke on Ultrasonic Testing. Mr. Dancy is a member of Electro-Circuits, Incorporated.

He gave his listeners a glimpse into the future of ultrasonic testing of engineering materials, discussing many ideas and applications still in development stages and demonstrating the value of several types of equipment now available. Most recent developments have hinged on the use of an ultrasonic transducer capable of focusing the sound waves so that rather minute details of the back side or flaws in a plate may be presented visually on an oscilloscope, he asserted.

San Francisco Bay Area Section also met October 20 at the Showboat Restaurant in Oakland, Cal. with about 56 members and guests present.

L. P. Sudrabin of the Electro Rust Proofing Corporation of Belleville, New Jersey spoke on Criteria Used in Cathodic Protection. He discussed various criteria in use today, summarizing the latest thinking on the subject. He also presented the highlights of the experimental work recently done on minimum current required to protect steel coupled to a copper cathode in various resistivity media, under the auspices of the T-2C Committee on Minimum Current Requirements for Cathodic Protection, of which he is chairman.



"PUTTING
Permanence
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CLEANING, COATING, WRAPPING & RECONDITIONING

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HOT DOPE
Straight from the Kettle
on PIPE PROTECTION

★
By Boyd Mayes

Most times I agree that the shoe-maker should stick to his last and pipe liners to pipe—but, since everybody is having his say on the FPC, gas transmission problems and price at the wellhead—feel it's fair to the public to remind 'em that all those words both pro and con which could confuse are covering up something *much more important than price issue*. As we see it—IT'S A MATTER OF PRINCIPLE or basic rights in business. We always figured that when a man got out of line—the law should get after him. But if he's a good member of the citizenry and disciplines himself—we never felt the law should lecture him. Seems to us somebody in the government was anticipating trouble—not waiting for any evidence of it. And we don't know of anything that regulates price better than competition between buyers and producers. Reckon that's somewhat the opinion of a lot of folks on this new problem.

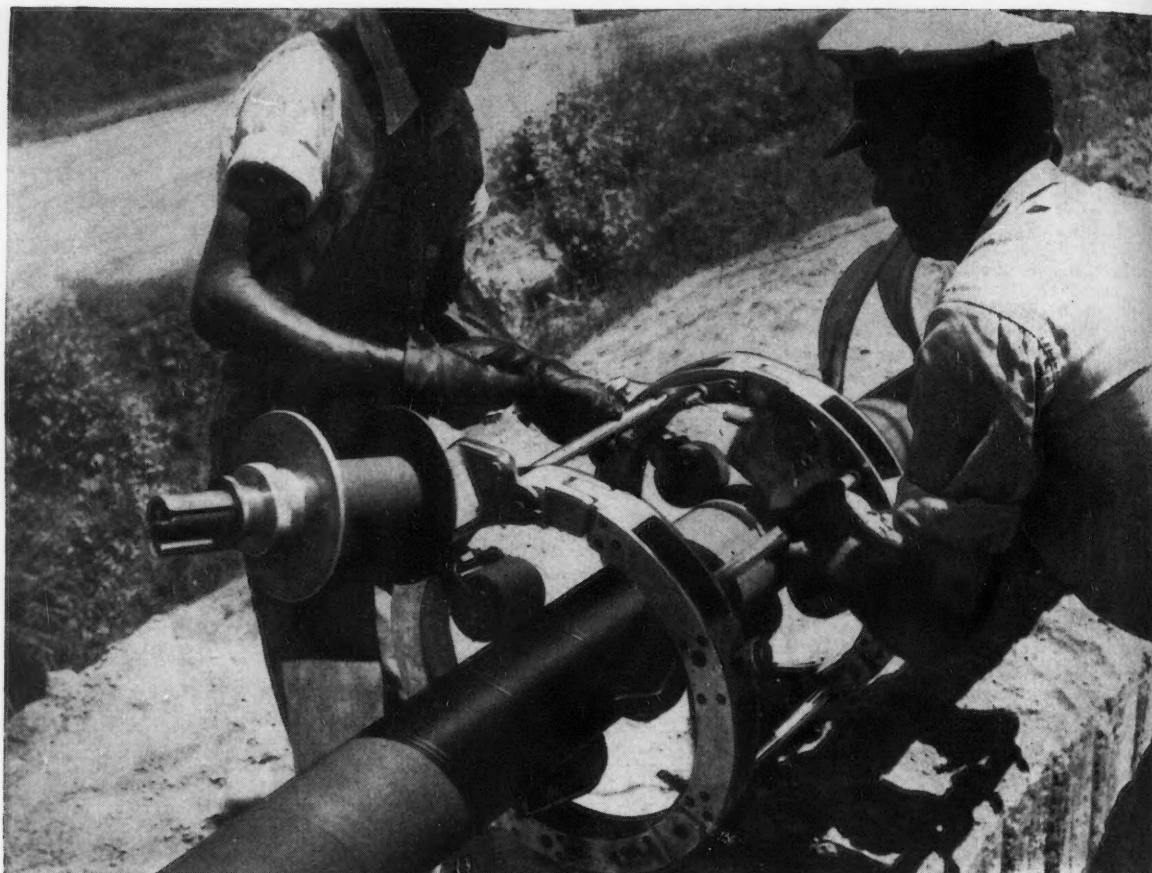
But now back to my pipe yard—we're happy to offer to those who need it, the finest in men, equipment and know-how in your pipe salvaging, coating and wrapping problems.

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Technical Committee News

Record Number of Meetings Planned for Chicago

Task Group Formed on Water Meter Corrosion

A new task group assigned to investigate corrosion in water meters was organized at the November 18 meeting held by Unit Committee T-4F on Materials Selection for Corrosion Mitigation in the Utility Industry. R. W. Henke, Chief Mechanical Engineer of the Research & Development Division of the Badger Meter Manufacturing Company in Milwaukee, Wisconsin was appointed chairman of the new group which has been assigned the designation T-4F-1 on Water Meter Corrosion.

During the meeting some interesting and appalling specific cases of corrosion problems resulting from poor design in plumbing installed under concrete floor slabs were related. One instance reported involved a residence that slipped downhill because of water leaking under the floor slab. This occurred about one year after completion of the building.

Galvanic Currents in Plumbing

The opinion was expressed that the rash of domestic plumbing failures may be caused by pipes being only partially covered with concrete leaving the remainder in contact with the soil. This type installation is likely to generate galvanic current which will result in early failure of the pipe. In corrosive soils pipes should not be placed in contact with the soil when installed under a concrete floor slab but should be protected with a good heavy bituminous coating with a fiber glass reinforcement.

Failure of Bolts Discussed

The snapping off of Tobin bronze bolts near the end of the thread was discussed. It was noted that similar failures have been experienced with steel bolts. Even replacement bolts failed. An investigation revealed that the threads were cut at such an angle that all the strain was thrown on one side of the bolt.

In a report on internal corrosion of copper tubing it was revealed that the corrosion is believed to be caused by residual chlorine in the water.

27 T-1 Members and Guests Hold Meeting On West Kansas Section

The November 3 meeting of T-1D and T-1H-2, West Kansas section of T-1D on Sour Oil Well Corrosion and T-1H Oil String Casing Corrosion was attended by 27 members and guests.

The purpose of the meeting was twofold. One to acquaint those engaged in corrosion work, who are not members of NACE with the work being done by technical committees of the association and the other to investigate the possibility of establishing a local section of NACE in West Kansas. Interest in forming a local section of NACE was very good and J. D. Alcott of the Anderson Prichard Oil Corp. in Great Bend, Kansas, was selected as chairman of the group to petition the South Central Region for permission to form a West Kansas Section. It is expected that petition will be delayed until after January 1, 1955.

In the portion of the meeting devoted to the work being done by the West Kansas Area group of T-1D the inhibitor program of each company represented was discussed with special emphasis on the amount of inhibitor used, volume or time of flush and the time between treatments. The discussion was particularly interesting in that there is considerable variation in the treating program of each company. The treating procedure varied from daily to weekly treatment and flushing time from a few minutes to four hours. There is also considerable difference in the amount of chemical used. The discussion served to illustrate that the selection of effective inhibitors is not a simple procedure and underlined the need of committee work such as that being done by NACE Unit Committee T-1D.

During the portion of meeting devoted to the work being done by the T-1H-2 West Kansas Area group of

(Continued on Page 84)

Schedule Shows 60 Groups Will Hold Sessions March 7-11

Sixty technical committees of the National Association of Corrosion Engineers are scheduled to hold meetings during the 1955 NACE Conference, Palmer House, Chicago, Illinois, March 7-11, 1955. This will be the heaviest schedule of technical committee meetings ever arranged for an NACE meeting. So that all members and other interested persons may know which committees are meeting and something of their activities, a Technical Committee Meeting Schedule for the 1955 NACE Conference is published in this and in the February issue of CORROSION. Below are names of each committee meeting with a short description of its activities and what is planned for the March meeting.

Group Committee T-1, Corrosion in Oil and Gas Well Equipment

Group Committee T-1 will meet on Monday, March 7 beginning at 9 am. E. C. Greco of United Gas Corporation, Shreveport, Louisiana, chairman of the group committee, has asked chairmen of unit committees under T-1 to make reports on the activities of their committees. The meeting will be opened to discussion at the end of each unit committee report and it is expected that much information will be forthcoming pertaining to corrosion of oil and gas well equipment.

Group Committee T-1 has appointed an editorial committee to write a book on "Corrosion of Oil and Gas Well Equipment" for the American Petroleum Institute. J. D. Sudbury, Continental Oil Company, Ponca City, Oklahoma, chairman of the editorial committee presented the first draft outline of the book at the October meeting of T-1. It is expected that a second draft of the book will be ready for discussion at the March meeting.

Unit Committee T-1A, Corrosion In Oil and Gas Well Equipment, Los Angeles Area

Unit Committee T-1A will not hold a meeting during the conference, however, Frank Davie, Shell Oil Company, Los Angeles, California, chairman, or P. W. Hill, Signal Oil & Gas Company, Long Beach, California, vice chairman, will report to T-1 on the activities of T-1A. This unit holds monthly meetings on various problems pertaining to corrosion in oil and gas well production equipment experienced in the Los Angeles area. A technical report prepared by the committee was published beginning on page 248 of the August 1954 issue of Corrosion.

(Continued on Page 84)

ERRATA SHEET—Index to Technical Committee News 1954

An errata sheet consisting of corrected versions of Pages 15 and 16 of the Index to Volume 10, 1954 has been inserted in all mailed copies of the January, 1955 issue of Corrosion. This errata sheet is intended for use by those having occasion to use the index published in the December, 1954 issue. The correction consists of the insertion of the dates of issue in the collected tables of contents on Page 16 for the contents of November and December.

- Additional copies of this errata sheet are available on request from Central Office, NACE.

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- Active and Junior NACE members may run without charge two consecutive advertisements annually under this heading, not over 35 words set in 8 point text type.
- Firms seeking employees, regardless of NACE membership, may run an advertisement of the same specifications indefinitely.
- Advertisements to other specifications will be charged for at standard rates.

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Corrosion Engineers. Positions available for graduate electrical engineers or equal. Previous field and design experience in corrosion mitigation systems required. Extensive travel involved. Salary open. The Hinchman Corp., Engineers, Francis Palms Bldg., Detroit 1, Mich.

Sales Representatives for DEL Protective Coatings. Protected territories available to qualified individuals or companies. No objection to carrying non-competitive lines. Write David E. Long Corp., 220 East 42nd St., New York 17, N. Y.

Corrosion Engineer—Graduate engineer with field and design experience in cathodic protection systems. Extensive travel. Salary open. Harco Corp., P. O. Box 7026, Cleveland 28, Ohio.

Manager—To manage reorganized department for sale of corrosion-proof materials. Good understanding of corrosion-proof materials or construction and sales experience in this field necessary. Location Cleveland. Write full details. CORROSION, Box 54-22.

Chemical Engineer, Chemist of Metallurgy Wanted

by well-known metal producer. Must have thorough knowledge of electrochemistry for development work on electrodeposition and corrosion protection by means of metallic coating systems. Work involves some travel and liaison with cooperating laboratories and plants. Applicant must be energetic, cooperative and have sound technical ability. Should have practical experience in plating. Submit complete resume of education and experience to CORROSION, Box 55-2.

CHEMICAL or METALLURGICAL ENGINEER

Leading chemical company has key position open in large Eastern plant. Should have a few years' experience with chemical plant corrosion problems.

Responsibilities will involve corrosion investigation for new and existing processes and development work in applying new materials of construction and corrosion prevention methods. Well equipped metallurgical corrosion laboratory and trained technicians available. CORROSION, Box 55-3.

Record Number of—

(Continued From Page 84)

recommend further needed research on these problems.

Unit Committee T-1F, Metallurgy

Unit Committee T-1F is scheduled to meet Tuesday, March 8, beginning at 9 am. F. J. Radd, Continental Oil Company, Ponca City, Oklahoma will report to T-1 at the Monday meeting.

T-1F continues to report on metallurgical problems related to oil and gas well equipment. Currently, emphasis is on sucker rods. A symposium on Petroleum Production Metallurgy will be presented Wednesday during the conference.

Unit Committee T-1G, Stress Corrosion Cracking

Unit Committee T-1G is scheduled to meet Thursday, March 10, beginning at 1:30 pm. R. S. Treseder, Shell Development Company, Emeryville, California, will report to T-1 at the Monday meeting.

T-1G is working on standardization of laboratory and field testing procedure relative to the stress corrosion cracking problem. The committee hopes to have a draft of the standardized procedure ready for discussion at the March meeting. T-1G also continues to direct a research project being conducted at Yale University on stress corrosion cracking. A progress report by T-1G was published beginning on page 413 of the November, 1954 issue of Corrosion.

Unit Committee T-1H, Oil String Casing Corrosion

Unit Committee T-1H is scheduled to meet Wednesday, March 9, beginning at 8 am. Jack L. Battle, Humble Oil & Refining Company, Houston, Texas, chairman, will report to T-1 at the Monday meeting.

T-1H has organized a study of oil string casing corrosion in the West Texas-New Mexico and West Kansas

Positions Available

Corrosion Engineer to test, design, estimate and supervise installation of cathodic protection on gas transmission lines. Give qualifications, references and salary expected. Graduate electrical preferred. Chief Engineer, Mississippi River Fuel Corp., 407 North 8th St., St. Louis 1, Mo.

Positions Wanted

Engineer—BSChE, 36, married, veteran. Experienced design, installation and maintenance of cathodic protection on pipelines and city distribution systems and in mobile communications. Prefer position with distribution company starting a corrosion program. Willing to relocate. Write CORROSION, Box 54-27.

B Ch E 1957, night student, age 23, family. Two years' experience corrosion protection, surface coating. Employed service engineer large industrial cleaner manufacturer. Want corrosion work in greater N. Y. area. CORROSION, Box 55-1.

Areas through task groups of the committee. The committee as a whole is currently emphasizing study of mitigating casing corrosion through use of cathodic protection. Some reports on this use of cathodic protection are expected at the March meeting.

Unit Committee T-1J, Oil Field Structural Plastics

Unit Committee T-1J is scheduled to meet Friday, March 11, beginning at 9 am. W. M. Thornton, Atlantic Refining Company, Dallas, Texas, or B. W. Bradley, Shell Oil Company, New York, New York, will report to T-1 on the committee's activities at the Monday meeting.

T-1J continues to report results of long term testing of plastics used as oil and gas well equipment. Six papers on the subject were presented at the October meeting of the committee and it is expected several reports will be given at the March meeting.

Unit Committee T-1K, Inhibitors for Oil and Gas Wells

Unit Committee T-1K is scheduled to meet Wednesday, March 9, beginning at 1:30 pm. J. C. Spalding, Sun Oil Company, Dallas, Texas, will report to T-1 at the Monday meeting.

T-1K recently completed a report entitled "Proposed Standardized Laboratory Procedure for Screening Corrosion Inhibitors for Use in Oil and Gas Wells." The report will be presented as a paper during the Chemical Inhibitor Symposium on Tuesday during the conference. The committee expects to discuss the report and future committee work during the March meeting.

Group Committee T-2, Pipe Line Corrosion

Group Committee T-2 is scheduled to meet Monday, March 7, beginning at 11 am. W. H. Stewart, Sun Pipe Line Company, Beaumont, Texas, chairman, will ask for a report from each unit committee under T-2. A new unit committee on prefabricated plastic films for application to pipe lines was authorized at the October meeting of T-2 and it is hoped a preliminary report on its organization will be available for the March meeting. T-2 has initiated work on minimum requirements for protecting pipe lines and drafts from unit committees are expected.

Unit Committee T-2A, Galvanic Anodes

Unit Committee T-2A is scheduled to meet Wednesday, March 9, beginning at 3:30 pm. The committee is studying galvanic anode operating installations through a task group and information on installations and other aspects of galvanic anodes are to be discussed during the March meeting.

Unit Committee T-2B, Anodes for Impressed Currents

Unit Committee T-2B is scheduled to meet Monday, March 7, beginning at 1:30 pm. The committee has an interim report nearing completion on carbon, graphite and steel anode tests. It is expected the report will be discussed at the March meeting. Members of T-2B have been developing information on high-silicon cast iron as anode material. The committee expects to hear some reports

(Continued on Page 87)

Record Number of—

(Continued From Page 86)

on these developments at the March meeting.

The committee has agreed to cooperate with the National Electrical Manufacturers Association in developing standards for metallic rectifier assemblies used in cathodic protection.

Unit Committee T-2C, Minimum Current Requirements

Unit Committee T-2C is scheduled to meet Monday, March 7, beginning at 8 am. T-2C is conducting controlled investigations of the methods of establishing minimum current requirements for adequate corrosion control by cathodic protection. The methods of study now being followed are to relate the flow of corrosion current or equivalent metal loss to specifically defined potential measurement techniques. Projects on which reports are expected to be available at the March meeting include: 1. Measurement of the pipe potential to a specifically located reference electrode made simultaneously with earth current meter observations. This study is being made on a recently installed 26-inch pipeline. 2. A paper tentatively entitled "Geometric Factors in Electrical Measurements Relating to Corrosion and Its Prevention." 3. Investigation of methods and mechanisms by which cathodic protection works. 4. Determine the relation of reference electrode location to the size and form of established anodic areas on a pipeline section, and 5. Study of "Null Method" on the pipe line section in Project 4.

The committee expects to prepare a draft of tentative standards suitable for establishing the minimum currents required for the cathodic protection of buried pipe for presentation at the March meeting.

A report by the committee was published beginning on page 232 of the August, 1954 issue of Corrosion.

Unit Committee T-2D, Standardization of Procedures for Measuring Pipe Coating Leakage Conductance

Unit Committee T-2D is scheduled to meet Wednesday, March 9, beginning at 1:30 pm.

T-2D recently approved a report entitled "Proposed Standard Method for Measuring Electrical Conductance of Coating on Buried Pipe Lines." The report will be discussed in detail at the March meeting. It is expected that considerable effort will be expended toward improving the report with ultimate revision in mind.

Unit Committee T-2E, Internal Corrosion of Product Pipe Lines and Tanks

Unit Committee T-2E is scheduled to meet Thursday, March 10, beginning at 9 am.

T-2E currently is conducting tests which ultimately will lead to development of suitable methods for evaluating internal corrosion in product pipe lines. It is expected that a report will be made at the March meeting on a number of in-line coupon tests that have been run since the last meeting of the committee in March, 1954.

Unit Committee T-2F, Internal Corrosion of Crude Oil Pipe Lines and Tanks

Unit Committee T-2F is scheduled to meet Wednesday, March 9, beginning at 1:30 pm.

T-2F continues to work on design and operation of pipelines and tanks in sour crude services. It is expected that some task groups of the committee will have reports ready. The committee is interested in working on a method for screening inhibitors for use in crude oil pipe lines and tanks and it is expected this will be discussed at the March meeting.

Unit Committee T-2G, Coal Tar Coatings for Underground Use

The meeting of T-2G in March will be

a closed meeting devoted to readying a proposed application specifications for coal tar enamel. The committee has completed the first draft of a coal tar coating specifications which it is expected will be submitted to Group Committee T-2 in March.

Unit Committee T-2H, Asphalt Type Pipe Coatings

Unit Committee T-2H is scheduled to meet Tuesday, March 8, beginning at 9 am.

T-2H expects to have a draft of minimum requirements for asphalt type coatings including application techniques ready for discussion at the March meeting.

(Continued on Page 88)



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Record Number of—

(Continued From Page 87)

Unit Committee T-2J, Pipe Wrapping Materials

Unit Committee T-2J is scheduled to meet Tuesday, March 8, beginning at 1:30 pm. T-2J was organized since the last NACE Conference and had its first meeting in October under the chairmanship of Clark A. Bailey, Johns-Manville Sales Corporation, New York, New York. The committee has begun work on minimum requirements for pipeline wrappers and expects to have a draft ready for discussion at the March meeting.

Group Committee T-3, General

Group Committee T-3 will hold a closed meeting of T-3 committee chairmen during the conference.

Unit Committee T-3A, Corrosion Inhibitors

Unit Committee T-3A is scheduled to meet Wednesday, March 9, beginning at 9 am. T-3A has recently completed a list of corrosion inhibitors which will be published in an early issue of CORROSION. The committee is expected to discuss the report at the March meeting and continue to report on information pertaining to corrosion inhibitors.

Unit Committee T-3B, Identification of Corrosion Products

Unit Committee T-3B is scheduled to meet Monday, March 7, beginning at 2:30 pm. T-3B is making a survey of literature on identification of corrosion products. A report on the survey to date will be given at the March meeting.

Unit Committee T-3C, Cost of Corrosion

Unit Committee T-3C is scheduled to meet Monday, March 7, beginning at 1:30 pm. It is expected there will be considerable discussion on items properly chargeable to corrosion and means of isolating and estimating these costs.

Unit Committee T-3D, Instruments for Measuring Corrosion

Unit Committee T-3D is scheduled to meet Monday, March 7, beginning at 3:30 pm. A task group of T-3D studying electrical holiday inspection of coatings is scheduled to meet an hour earlier.

T-3D will discuss instruments for measuring corrosion and possibly hear a report by its task group during the March meeting. The committee hopes to be able to organize a symposium for a NACE Conference in the next year or so.

Unit Committee T-3E, Railroads

Unit Committee T-3E is scheduled to meet Wednesday, March 9, beginning at 9 am.

T-3E will hear a report from the task group on corrosion of railroad tank cars. The report will be on suggested procedures for preparing tank cars interiors for lining and will be submitted as an official committee report soon after the March meeting.

T-3E will also hear a report from the task group on corrosion in railroad hop-

per cars. This report will be on the application of magnesium anode material on steel wire tested on a model railroad hopper car containing coal with a sulfur content of 2.11 percent. T-3E will discuss use of inhibitors in hopper cars and deicing platforms.

Unit Committee T-3F, Corrosion by High Purity Water

Unit Committee T-3F is scheduled to meet Tuesday, March 8, beginning at 1:30 pm. T-3F will present a symposium on Wednesday morning of the conference. Three reports will be given as papers at the symposium. The subjects of the reports are 1. Importance of high purity water data to industrial applications, 2. Corrosion resistance of materials in high purity water, 3. Pilot plant experience with high purity water.

Unit Committee T-3G, Cathodic Protection

Unit Committee T-3G is being organized by T. P. May of the International Nickel Company, Inc., New York. A preliminary meeting of the committee is planned prior to the March meeting for organizational purposes. The committee will meet during the conference and the time for the meeting will be published as soon as the information is available. T-3G will study problems dealing with cathodic protection applications other than pipelines and utilities.

Unit Committee T-3H, Tanker Corrosion

Unit Committee T-3H is scheduled to meet Tuesday, March 8, beginning at 2 pm. T-3H was formally organized at the South Central Regional Meeting in Dallas, Texas, in October. W. S. Quimby, The Texas Company, New York, New York is temporary chairman and primarily responsible for its organization. The March meeting of T-3H will consist of several discussions headed by qualified discussion leaders. Several members of the committee have agreed to submit data at the meeting. The data will be on laboratory and shipboard tests and experience on tankers in both clean and dirty service. Of special interest will be some recently developed data on inhibitor systems for tankers.

Group Committee T-4, Utilities

Group Committee T-4 will hold a closed meeting of T-4 unit committee chairmen during the conference.

Committee T-4A, Effects of Electrical Grounding on Corrosion

Unit Committee T-4A is scheduled to meet Wednesday, March 9, beginning at 9 am. The program for the March meeting of T-4A will consist of discussion of electrical grounding practices by the individual committee members.

Unit Committee T-4B, Corrosion of Cable Sheaths

Unit Committee T-4B is scheduled to meet all day Tuesday, March 8, beginning at 9 am. The meeting will hear reports of the task groups in the following sequence:

T-4B-6, Stray Current Electrolysis,

beginning at 9 am. T-4B-6 currently is preparing a technical report on general practices pertaining to bonding and grounding cable sheaths for corrosion mitigation in the utilities industry. The report will be discussed at the meeting.

T-4B-1, Lead and Other Metallic Sheaths, beginning at 10:30 am.

T-4B-2, Cathodic Protection beginning at 11:30 am.

T-4B-3, Tests and Surveys, beginning at 1:30 pm. This task group recently completed an interim report which was published in the December, 1954 issue of CORROSION.

T-4B-4, Protection of Pipe Cables, beginning at 2:30 pm. This task group completed an interim report this year. The report was published beginning on page 299 of the September, 1954 issue of CORROSION.

T-4B-5, Non-Metallic Sheaths and Coatings, beginning at 3:30 pm.

Unit Committee T-4D, Corrosion by Deicing Salts

Unit Committee T-4D is scheduled to meet on Monday, March 7, beginning at 2 pm.

T-4D will hear progress reports from task groups currently working on procedures for conducting field tests on the corrosive effects of deicing salts and coordinating field programs between cities and transportation companies. A progress report will also be heard on a supplement for the committee bibliography on snow removal methods.

Unit Committee T-4E, Analysis of Domestic Waters

Unit Committee T-4E is scheduled to meet Tuesday, March 8, beginning at 3:30 pm.

T-4E will hear a report on the determination of seasonal variation of six typical municipal waters of the United States. The report will be from the viewpoint of correlation of waters. A committee questionnaire also will be discussed at the March meeting.

Unit Committee T-4F, Materials Selection for Corrosion Mitigation in the Utility Industry

Unit Committee T-4F is scheduled to meet Monday, March 7, beginning at 9:30 am.

T-4F currently is accumulating information on cost to the utility industry resulting in poor choice of materials for initial installations. The committee is also devoting considerable time to corrosion problems encountered by the plumbing industry especially those problems resulting from improper installation procedures and protective measures.

Group Committee T-5, Corrosion Problems in the Process Industries

Group Committee will hold a closed meeting of the T-5 unit committee chairmen during the conference.

Unit Committee T-5A, Chemical Manufacturing Industry

Unit Committee T-5A is scheduled to meet Monday, March 7, beginning at 4 pm. The meeting will be essentially a discussion of the task group assignments. The task groups of T-5A will meet as follows:

T-5A-1, Sulfuric Acid, beginning at

(Continued on Page 89)

Record Number of—

(Continued From Page 88)

1:30 on Monday. The task group will discuss a questionnaire to be used in soliciting data regarding the performance of various materials in sulfuric acid services. The task group will hear a report on an annotated bibliography being prepared by members of the group.

T-5A-3, Acetic Acid, beginning at 1:30 pm on Tuesday, March 8.

T-5A-4, Chlorine, beginning at 3 pm on Monday. This task group will discuss a bibliography that has been prepared and which will soon be made available for publication.

T-5A-5, Nitric Acid, beginning at 9 am on Monday. This task group will hear reports on the following committee projects: 1. Preparation of a general nitric acid questionnaire, 2. Survey of critical problems encountered in nitric acid manufacture, and 4. An interim report of the committee on results of 1 and 2.

Unit Committee T-5B, High Temperature Corrosion

Unit Committee T-5B is scheduled to meet Friday, March 11, beginning at 9 am.

T-5B has completed a report on materials for use under high temperature conditions. It is expected the report will be discussed at the March meeting.

Unit Committee T-5D, Plastic Materials of Construction

Unit Committee T-5D is scheduled to meet Tuesday, March 8, beginning at 9 am.

T-5D was organized formally in October 1954, although a planning meeting was held a month earlier. In this short period, the committee has grown to a membership of 117. Results of a survey of the committee were published beginning on Page 9 of the Technical Committee News Section of the November, 1954 issue of CORROSION. At the March meeting the committee will hear the results of a more complete questionnaire. There also will be discussions from eight task groups.

Group Committee T-6, Protective Coatings

Group Committee T-6 is scheduled to meet beginning at 2 pm on Wednesday, March 9. The meeting will be a discussion of the activities of the unit committees under T-6.

Unit Committee T-6A, Organic Coatings and Linings for Resistance to Chemical Corrosion

Unit Committee T-6A is scheduled to meet Monday, March 7, beginning at 9 am. A report entitled Application Techniques, Physical Characteristics and Chemical Resistance of Polyvinyl Chlor-Acetates was published beginning on Page 349 of the October, 1954 issue of CORROSION. Two more reports have been completed, one on epoxies and one on chlorinated rubber, which will be discussed at the March meeting. There also will be discussion of drafts of reports on rigid vinyls, fluorocarbons, polyesters, phenolics and furanes, vinylidene chloride, polymers and rubber, elastomers and heavy linings.

Unit Committee T-6B, Protective Coatings for Resistance to Atmospheric Corrosion

Unit Committee T-6B is scheduled to meet Monday, March 7, beginning at 1:30 pm.

T-6B has completed, except for some minor corrections, a comprehensive chart on properties of paint resistant to atmospheric corrosion. The chart will be discussed at the March meeting and will be presented to Group Committee T-6 as a committee report.

Unit Committee T-6C, Protective Coatings for Resistance to Marine Corrosion

Unit Committee T-6C is scheduled to meet Wednesday, March 9, beginning at 1:30 pm. T-6C will discuss data acquired

and results of performance tests that have been under surveillance by the committee.

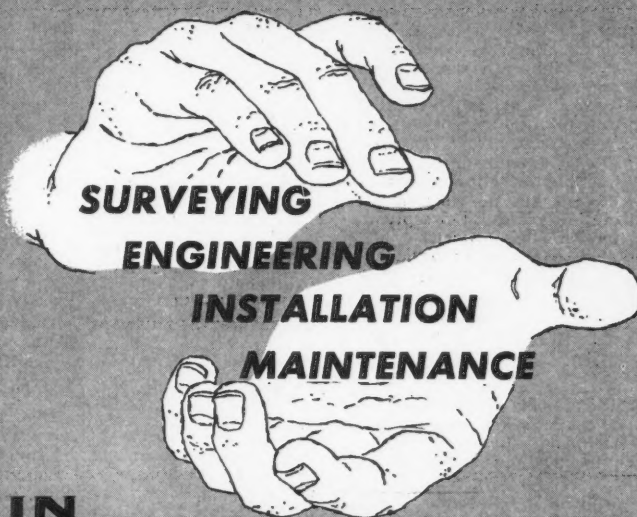
Unit Committee T-6E, Protective Coatings in Petroleum Production

Unit Committee T-6E is scheduled to meet Thursday, March 10, beginning at 12:30 pm.

A new project for T-6E will be discussed at the March meeting. It is expected the new project will include suggested specifications to be used as a guide only for the application, equipment, method of application and inspection of coatings. The committee expects to include offshore structures in its study and may expand its efforts to include

(Continued on Page 90)

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Record Number of—

(Continued From Page 89)

harbor structural exposures in salt water marine environment.

Unit Committee T-6G, Surface Preparation for Organic Coatings

Unit Committee T-6G is scheduled to meet Thursday, March 10, beginning at 9 am. T-6G will review an outline of specifications for surface preparation for painting aluminum.

Unit Committee T-6H, Glass Linings and Viterous Enamels

Unit Committee T-6H is scheduled to meet Wednesday, March 9, beginning at 3:30 pm.

Unit Committee T-6K, Corrosion Resistant Construction With Masonry and Allied Materials

Unit Committee T-6K is scheduled to meet Thursday, March 10, beginning at 9 am. T-6K will discuss a report being prepared by the committee.

Unit Committee T-6R, Protective Coating Research

Unit Committee T-6R is scheduled to meet Tuesday, March 8, beginning at 9 am. T-6R will hear a report on the project being sponsored by the Federation of Paint & Varnish Production Clubs on minimum paint film thickness on steel for economic protection against corrosion.

R. H. Steiner, Atlas Mineral Products Company, Mertztown, Pennsylvania, chairman of T-6R, is the T-6 representative on the FPVPC project.

T-6R will also report on projects to be proposed for study by T-6 committees.

Report on Epoxy Coatings On Agenda of T-6A

The final draft of a report on epoxies as organic coatings for resistance to chemical corrosion will be reviewed at the March meeting of Technical Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion. The report was reviewed at a meeting of the committee held in Chicago October 13. The epoxy report will be reviewed by technical groups of three companies prior to the March meeting and it is hoped the report will be approved at the meeting for publication as an official committee report.

A draft of a report on chlorinated rubber also will be submitted to the committee at the March meeting for consideration as an official report for publication.

Preliminary reports on rubber and elastomers and heavy linings, vinylidene chloride polymers, phenolics and furanes, polyesters, fluorocarbons and rigid vinyls will be submitted to the chairman of T-6A early in 1955 and it is hoped all these will be ready for review and discussion at the March meeting.

The reports are being prepared by task groups under T-6A. The task groups and their chairmen are as follows:

T-6A-1 Epoxys, C. G. Munger, Amercoat Corporation, Southgate, Calif., chairman.

T-6A-2 Chlorinated Rubber, F. Shankweiler, Hercules Powder, Wilmington, Del., chairman.

NACE Technical Committees Reach High Level Of Activities; Publish Six Reports in 1954

The year 1954 was a year of exceptional activity on the part of NACE's technical committees. More committee reports were published in 1954 than in any other single year, more committee meetings held with larger attendance and the committees in general were more active than in most previous years.

There were six technical committee reports published in 1954 as against four in any previous single year. In addition to the six reports published there were three more committee reports completed in 1954 to be published early this year.

Reports published in 1954 are:

Publication 54-2—Some Observations of Cathodic Protection Potential Criteria in Localized Pitting, a report of Unit Committee T-2C on Minimum Current Requirements for Cathodic Protection, beginning on Page 232 of the August issue of Corrosion.

Publication 54-3—Pipe-Type Cable Corrosion Protection Practices in the Utilities Industry, first interim report of Unit Committee T-4B on Corrosion of Cable Sheaths, beginning on Page 299 of the September issue of Corrosion.

Publication 54-4—Application Techniques, Physical Characteristics and Chemical Resistance of Polyvinyl Chlor-Acetates, a report by Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion, beginning on Page 349 of the October issue of Corrosion.

Publication 54-5—Sulfide Corrosion Cracking of Oil Production Equipment, a report of Unit Committee T-1G on Sulfide Stress Corrosion Cracking, beginning on Page 413 of the November issue of Corrosion.

Publication 54-6—Tests and Surveys for Lead Sheathed Cables in the Utilities Industry, second interim report of Unit Committee T-4B on Corrosion of Cable Sheaths, beginning on Page 445 of the December issue of Corrosion.

Publication 54-7—Survey of Corrosion Control in California Pumping Wells, a report of Unit Committee T-1A on Corrosion in Oil and Gas Well Equipment in the Los Angeles area, beginning on Page 248 of the August issue of Corrosion.

News Stories Published

In addition to these official technical committee reports, 94 articles concerning technical committee activities were published in the Technical Committee News Section of 1954 Corrosion. Three of these articles were extensive reviews of committee work, these were:

Service Reports Given on Oil Field Plastic Pipe concerning activities of Unit Committee T-1J on Oil Field Structural Plastics, beginning on Page 9 of the September issue of Corrosion; Oilfield Structural Plastics Test Data Are Given, another report on the activities of Unit Committee T-1J, beginning on Page 17 of the July issue of Corrosion and 150 Attend Dallas Plastic Materials Session, a report on activities of Unit Committee T-5D on Plastic Materials of Construction in the process industries, beginning on Page 9 of the November issue of Corrosion. Reprints of all three of these articles have been in demand.

Committee reports completed in 1954 scheduled for publication early this year include: Tentative Standard Method for Measuring Electrical Conductance of Coating on Buried Pipe Lines, a report of Unit Committee T-2D on Standardization of Procedures for Measuring Pipe Coating Leakage Conductance; Proposed Standardized Laboratory Procedures for Screening Corrosion Inhibitors for Use in Oil and Gas Wells, a report of Unit Committee T-1K on Inhibitors for Oil and Gas Wells; Some Corrosion Inhibitors—A Reference List, a report of Unit Committee T-3A on Corrosion Inhibitors. Several more committee reports are expected to be completed for publication in 1955.

Six Units Were Formed

There were six new Unit Committees organized during 1954 and two more have been proposed for organization. Committees organized during 1954 were: T-2J, Pipe Wrapping Materials; T-3F, Corrosion by High Purity Water; T-3G, Cathodic Protection; T-3H, Tanker Corrosion; T-5D, Plastic Materials of Construction and T-6R, Protective Coatings Research. The unit committees in the proposal stage are: Prefabricated Plastic Films for Application to Pipe Lines under Group Committee T-2 on Pipe Line Corrosion, and Offshore Drilling and Production Corrosion Problems under Group Committee T-1 on Corrosion in Oil and Gas Well Equipment.

Unit Committee T-2J held an organizational meeting during the South Central Region meeting in Dallas last October. The committee was organized to study problems connected with pipe wrapping materials used in all types of pipe line protective coating applications. The committee has initiated work on a minimum requirements for pipe wrapping materials and expects to have a draft ready for discussion at the March meeting.

T-3F held an organizational meeting in Kansas City during the 1954 NACE Conference. The committee is studying corrosion problems related to high purity water. A committee report will be given in the form of a symposium at the 1955 NACE Conference in Chicago.

Cathodic Protection Unit

T-3G was recently authorized for organization. Dr. T. P. May of The International Nickel Co., Inc. has been appointed chairman of the committee and expects to hold an organizational meeting sometime before the March NACE meeting. T-3G will study those problems of cathodic protection not connected with pipe line applications or applications within the utilities

(Continued on Page 91)

T-6A-3 Rubber and Elastomers and Heavy Linings, H. C. Klein, B. F. Goodrich, Cuyahoga Falls, Ohio, chairman.

T-6A-4 Vinylidene Chloride Polymers, A. E. Young, The Dow Chemical Co., Midland, Michigan, chairman.

T-6A-5 Phenolics and Furanes, Forest Baskett, Lynn McGuffey Co., Houston, Texas, chairman.

T-6A-6 Polyesters, D. F. Siddall, The United States Stoneware Co., Akron, Ohio, chairman.

T-6A-7 Fluorocarbons, J. J. Ondrejcin, E. I. duPont de Nemours & Co., Inc., Wilmington, Del., chairman.

T-6A-8 Rigid Vinyls, C. G. Munger, Amercoat Corporation, Southgate, Calif., chairman.

High Purity Water Corrosion Resistant Materials Are Discussed

Materials of highest resistance to corrosion by high purity water at temperatures of 600 F and in some instances higher include austenitic stainless steels, precipitation hardening stainless steels, cobalt alloys, gold, platinum, titanium, zirconium and hafnium according to a report recently given by A. H. Roebuck of the Continental Oil Company in Ponca City, Oklahoma. Mr. Roebuck is a member of NACE Unit Committee T-3F on Corrosion by High Purity Water and chairman of NACE Unit Committee T-3B, Corrosion Products.

The corrosion rates of the materials listed as highly resistant to corrosion by high purity water are in the order of 3 mdd. Of the materials and classes listed, platinum, AISI Types 316 and 347 stainless steels, titanium and zirconium exhibit the highest all around resistance.

Materials of intermediate corrosion resistance include aluminum and aluminum alloys, chromium, 70-30 copper-nickel, cobalt, ferritic and martensitic stainless steels, nickel and nickel alloys. Under certain conditions these metals may exhibit high corrosion resistance, however, in general they do not possess the overall resistance to attack shown by the metals listed first. These intermediate materials must be used with caution.

Materials of lowest resistance include

copper, bronzes, magnesium, plain carbon steels and silver. Of these, plain carbon steels merit special consideration and further study. Other materials in this group should not be used in systems of the type under consideration, without further evaluation, Mr. Roebuck said.

Of the factors affecting corrosion, the system temperature, the system gas concentration (particularly with respect to dissolved oxygen) and the metal surface condition are important. The steels, nickel and nickel alloys, copper and copper alloys, show highest resistance in systems having low oxygen concentrations.

Crevice Corrosion Important

In discussing Dr. Roebuck's report D. J. DePaul, Westinghouse Electric Corp., Pittsburgh, chairman of NACE T-3F on Corrosion by High Purity Water said one of the most important corrosion problems associated with materials in contact with water is crevice corrosion. He explained there is very little information on crevice corrosion in published literature. This form of corrosion has been a problem of major concern in design considerations and choice of materials for water cooled reactor components.

In testing in high purity water at temperatures up to 650 F the mechanism of

(Continued on Page 92)

NACE Technical—

(Continued From Page 90)

industry. NACE members interested in becoming a member of T-3G should contact Dr. May at his office, 67 Wall Street, New York, New York.

T-3H held an organizational meeting during the recent South Central Region meeting in Dallas. The committee will assimilate information pertaining to corrosion in tanker compartments in clean crude service, dirty crude service and petrochemical service. An interesting meeting is being planned for March where a good deal of information will be forthcoming.

T-5D organized during the recent South Central Region meeting in Dallas. The committee has set up eight task groups to study plastic materials of construction in the process industries. Results of a preliminary questionnaire circulated by the committee were published in the Technical Committee News Section beginning on Page 9 of the November issue of Corrosion.

T-3F held its organizational meeting in Kansas City during the 1954 NACE Conference. A second meeting was held during the Western Region meeting in November. The committee currently is preparing a report on thirty-two 20-inch valves that have been in service in a filter plant for the past 18 years. This report will be on the cost of repairing corrosion damage suffered by the valves.

T-6R held a preliminary meeting during the Kansas City NACE Conference. This committee was organized to investigate problems that would be likely T-6 committee projects.

In addition to the new unit committees organized, there were 11 new task groups appointed by unit committees for the study of specific problems within the scope of the parent unit committees.



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Dow magnesium anodes plus expert engineering and installation services are now offered to industry by a new firm, Yale W. Titterington and Hugh A. Brady, in charge of service, emphasize the company's experienced personnel and competitive position in the cathodic protection field.

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High Purity Water—

(Continued From Page 91)

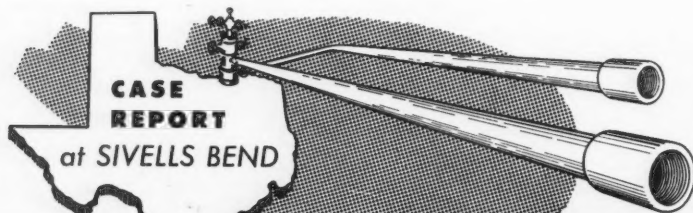
attack has been fairly well established as an oxygen concentration cell. Crevice corrosion is undesirable because it produces relatively large amounts of corrosion product at the mouth of a crevice which, in applications involving moving parts with small clearances, may cause excessive wear or complete seizure. Figure 1 illustrates the form in which this type of corrosion normally occurs. This is a standard contact corrosion test sample and is shown disassembled in order to reveal the location and extent of buildup of the corrosion product. It can be seen that a narrow ridge of corrosion product has formed at the perimeter of the contact area which outlines the posi-

tion of the sleeve in the assembled couple. It should be noted also that little or no corrosion has occurred within the crevice area. This is very characteristic in the type of crevice corrosion experience in high purity water service.

Table 1 indicates susceptibility of various materials to crevice corrosion. The extent of buildup at the perimeter of the contact area normally decreases with increasing corrosion resistance of the material. Certain materials, namely the straight chromium stainless steels, high copper and high nickel bearing alloys are also subject to pitting on the area in contact. This type of pitting does not result from galvanic effects, since it occurs with couples made up of the same materials and with these materials in contact with plastics. The pitting observed is usually minor in nature and is



Figure 1—Example of crevice corrosion buildup.



PROOF AGAIN THAT TUBE-KOTE PIPE LININGS SAVE PRODUCTION TIME

In the Sivelles Bend Field in Cooke County, Texas, a major oil company was having trouble with heavy paraffin deposition in flow lines during the winter months. These were surface flow lines and paraffin had to be removed by hot oil circulation as frequently as twice a week, depending upon the severity of the cold weather.

To eliminate this problem, they installed 4500 feet of 2" flow line pipe which had been coated with Tube-Kote's TK-2 plastic lining. The TK-2 lined pipe has now been in service for **SIX YEARS** and no paraffin accumulation has occurred despite the fact that this line has at times been covered with snow and ice. Some of the joints of the coated pipe were bent to go around corners, yet even these sections had no paraffin deposition.

Such excellent service obtained by Tube-Kote linings has caused this oil company and others to specify Tube-Kote lined pipe.

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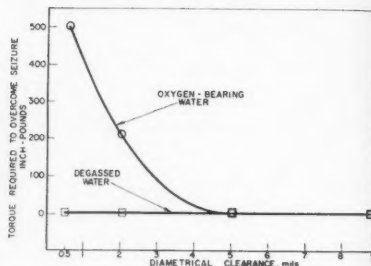


Figure 2—Effect of oxygen and clearance on crevice corrosion at 500 F.

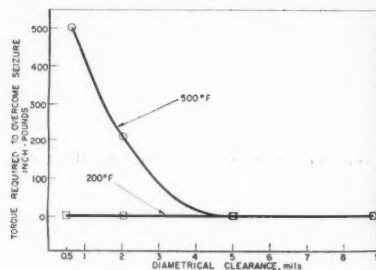


Figure 3—Effect of temperature on crevice corrosion in oxygen-bearing water.

normally of no real consequence except in moving parts with close clearances.

Variables Effect Recorded

Figures 2 and 3 illustrate the effect of temperature, oxygen content and clearance on crevice corrosion. Although most of the work was done on the more corrosion resistant materials such as the 18-8 type stainless steels, the information applies to most of the materials studied. Figure 2 shows that this form of crevice corrosion is dependent on oxygen that the bad effects of oxygen can be tolerated if clearances are maintained in excess of 5 mils. Figure 3 illustrates the effect of temperature on

(Continued on Page 93)

High Purity Water—

(Continued From Page 92)

Table 1—Susceptibility of Various Materials to Crevice Corrosion

Material	Type of Attack
18-8 Type Stainless Steels	Corrosion Buildup
Cobalt Base Alloys	Corrosion Buildup
Copper Base Alloys	Corrosion Buildup and Pitting
Nickel Base Alloys	Corrosion Buildup and Pitting
Straight Chromium Stainless Steels	Corrosion Buildup and Pitting

crevice corrosion. At the lower temperature there is essentially no crevice corrosion problem, especially with the more corrosion resistant materials. Normally, the extent of contact corrosion found at 200 F amounts to nothing more than a discoloration of the metal without any measurable buildup.

It is evident that it is essential during the design stage to consider such items as materials, clearance in moving parts, extent of movement, temperature and oxygen content of the water. Permanent crevices formed by such items as threaded joints and flanged or socket weld joints are of no practical concern, since the amount of metal lost is exceedingly small and the corrosive buildup formed at the mouth of the crevice does not produce any harmful effects.

Pitting Sometimes Important

Considerable attention so far has been directed toward the importance of buildup, however, there are certain applications where pitting in crevices is more important than buildup. For instance, the use of stainless steel 410 as a rivet material is generally considered a good choice because the material does not work harden readily. However, it is not considered good practice in high purity water applications since crevice corrosion pitting can proceed along the length of a rivet at a fairly rapid pace. Penetration rates in the order of 70 mils per year have been observed in water at temperatures between 200 F and 500 F. This problem was solved by using a special high chromium and nickel stainless steel, Carpenter No. 10, having desirable riveting properties and which is not susceptible to accelerated corrosion within the crevice. Pitting also has been a problem with plain ground springs where the last turn forms a crevice with the supporting structure. Unfortunately, many of the materials having good spring properties are in the group of materials that exhibit pitting; therefore, for lack of a better material it has been necessary to plate the flat ends of the last turns with chromium which is not susceptible to pitting under these conditions.

Even though the information discussed here was based on studies conducted in high purity water, there is some indication that much of the information is applicable to general industrial water problems.

Discussions of technical material printed in CORROSION are not limited to those actually originating at the presentation of papers at meetings.

Identification of Corrosion Products Is T-3B Topic

The October 13 meeting of T-3B on Corrosion Products was attended by several representatives from the oil industry. Several problems in the oil industry which are covered by T-3B committee activity were discussed. Of special interest was a problem concerning the identification of corrosion products forming within a pipe line used to transport refined petroleum products. Concern was expressed over the possibility corrosion product composition would change during the period between sampling and analysis. The question of where to most advantageously take sam-

ples arose. It was the consensus that it was desirable to obtain samples as close to the corroding area as possible. Several present at the meeting from the oil industry have accepted membership on it.

Hutt Is Elected to Head Porcelain Enamel Institute

Glenn A. Hutt, vice president of Ferro Corp. succeeded W. A. Barrows, president of Barrows Porcelain Enamel Co., as president of Porcelain Enamel Institute during the institute's 23rd Annual Meeting in White Sulphur Springs, W. Va., on September 29-October 1.

Lists of literature available from NACE may be had on request.

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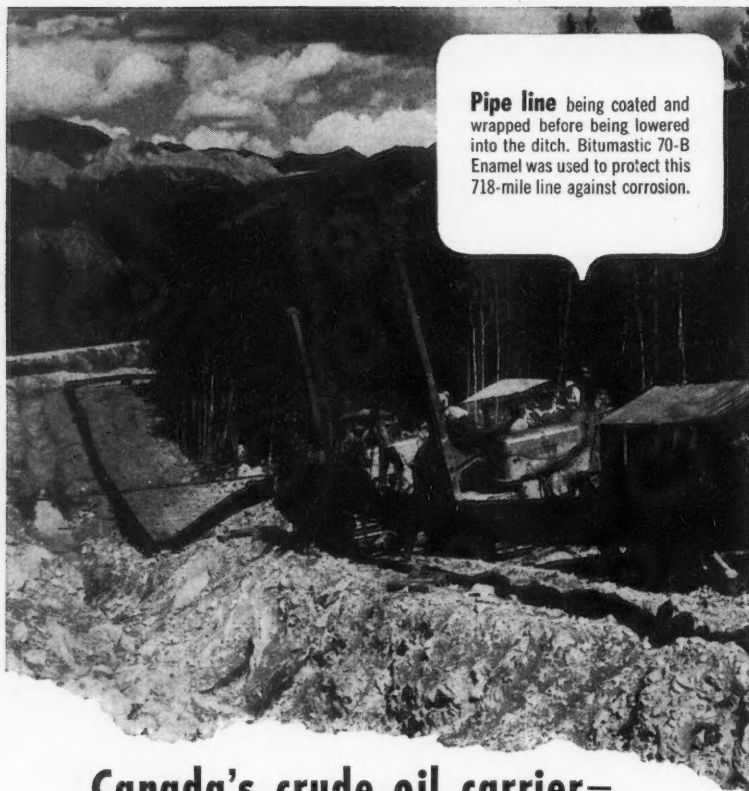
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Corrosion Makes Changes In Page Numbering System

In an effort to make the use of indices in Corrosion easier and at the same time preserve the present accumulative numbering of the Technical and Corrosion Abstracts Sections a revision of the system for numbering pages has been put into effect in Corrosion effective with the January, 1955 issue. This calls for consecutive numbering of pages from first to last in each issue, with all indices published in the issue referring to these pages.

An additional series of numbers will be carried in the lower outer margins of the Technical Section, followed by the letter "t." This series will start with Page 1t in January and be accumulative throughout the volume to end with the last page of the Technical Section in December, the last issue of the volume.

Similarly a series of numbers will be carried in the lower outer margins of the Corrosion Abstract Section followed by the letter "a," as has been the practice in recent years. This series will be accumulative throughout the year beginning with Page 1a in January and ending with the last page of the Corrosion Abstract Section in December, the last issue of the volume.

Annual indices compiled in both the Technical and Corrosion Abstract Sections will refer to the accumulative numbers only.

The change is expected to make easier the issue-to-issue use of Corrosion while continuing the present practice of numbering the two technical sections accumulatively.

Smith Named to NACE Board as Director

P. H. Smith, Nooter Corp., St. Louis, has been named by the board of directors of the National Association of Corrosion Engineers to fill the unexpired term as director representing corporate members vacated by the resignation of J. Pat Casey, formerly of the Crane Company, Chicago. Mr. Casey now is with Cramet, Inc., Chattanooga, Tenn.

Mr. Smith has been a member of NACE since January 1949. He was chairman of the Greater St. Louis Section in 1949-50 and also participated in arrangements for the Sixth Annual Conference and Exhibition of NACE which was held in St. Louis in April, 1950.

Air Pollution Course Is Scheduled by NYU

A course in the fundamentals of the measurement and prevention of atmospheric pollution is being offered by the Institute of Industrial Medicine of the New York University post graduate medical school, a unit of New York University-Bellevue Medical Center, in cooperation with NYU college of engineering. The class will meet once a week for 15 weeks February 10 through May 26. Tuition is \$60. Application should be made through the Office of the Dean, New York University Post-Graduate Medical School, 550 First Ave., New York 16, N. Y.



General News

Papers at Italian National Corrosion Meeting Are Listed

Electrochemical Center Sessions Held at Milan

A National Meeting on Corrosion, sponsored by Centro di Elettrochimica of the Associazione Italiana, was held in Milan, October 8-10, 1953. The papers and discussions presented have been published in a Special Issue of *LA METALLURGIA ITALIANA* as a part of Volume XLVI (46) (1954).

The papers are as follows:

The Passivity Phenomena of Metals and Alloys, R. Pointelli—pp. 5-28.

The Passivity of Zinc As It Relates to Aeration Conditions, G. Bianchi—pp. 29-30.

Some Features of Oxygen Is Influence in Wet Corrosion Phenomena, G. Bianchi—pp. 30-32.

Passivity Phenomena in Stainless Steels, A. Ferri—pp. 33.

Passivity Conditions Produced by Oxidizing Agents on Ordinary and Special Steels, A. Indelli—pp. 34-35.

Some Considerations on the Use of Metallic Materials and on Corrosion in the Chemical Industry, G. Pastonesi—pp. 37-41.

The Influence of Dissolved Gases on Fitting of Stainless Steels, C. Bighi—pp. 42-43.

Considerations on the Possibility of Increasing the Protective Power of Anodic Oxidation Film on Aluminum, G. P. Bolognesi—pp. 44-45.

Evaluation Method of the Local Corrosion Current on Zirconium, M. Maraghini and P. Van Rysselberghe—pp. 45-46.

Some Corrosion Problems and Protective Means in a Petroleum Refinery, P. Daino—pp. 47-50.

A Review of the Corrosion Resisting Materials Developed by the Modern Technique, P. Negretto—pp. 51-53.

Potable Waters and Their Corrosive Action on Ferrous Materials, R. Sandrinelli—pp. 54-58.

Protection Against Corrosion of Substances Having an Inhibitant Action, L. Cavallaro—pp. 59-63.

Participation to the Study of Inorganic Inhibitors, U. Bertocci—pp. 64-66.

Protection Against Corrosion by Means of Parkerizing, P. De Cerna—p. 67.

The Use of Inhibitors in the Pickling of Castings, B. Domenicali—p. 68.

The Use of Inhibitors in the Chemical Descaling of Boilers, B. Domenicali—pp. 69, 88.

Some Investigations on Stimulating and Wetting Inhibitors of Pickling and Phosphating Processes, L. Felloni—pp. 70-72.

Adsorption and Overvoltage in the Action of Pickling Inhibitors, A. Indelli and P. Bolognesi—pp. 73-74.

Research on Inhibitors in Vapor Phase, G. Mantovani—pp. 75-76.

Practical Considerations on the Theories on Protection Against Corrosion

of Industrial Equipment, F. Schieroni—pp. 77, 95.

Corrosion and Protection of Buried Metallic Materials, M. Jacopetti—pp. 79-88.

Tin as a Protection Against Corrosion, S. C. Britton—pp. 89-90.

Investigation of Some Cases of Pipe Corrosion in Radiant Panels, E. Donati, G. Beretta—pp. 91-95.

Cathodic Protection of Underground Metallic Pipes and Structures, E. Gerosa—pp. 96-97.

Economic Features of Cathodic Protection, T. Nanni, A. Compostella—pp. 98-100.

Contribution to the Study of Hot Oxidation of Metals and Alloys, F. De Carli and P. Spinetti—pp. 101-107.

Testing and Checking Methods in the Metal Corrosion Field, G. Bianchi—pp. 109-112.

Refractory Ceramic Coatings for the Protection of Metals at High Temperature, E. Crepaz—pp. 113-116.

Testing Methods of Action of Pigments in Varnishes, C. Bighi, G. Mantovani—pp. 117-118.

Evaluation of Inhibiting Power Through Polarization Curves, G. Bombarda—pp. 119-120.

Use of Electrochemical Methods in Material Testing, L. Cavallaro, A. Indelli—pp. 120-121.

Corrosion Testing Methods Used at the ISML, G. Luft—pp. 122-124.

Analysis of Metallic Sound as a Measurement of the Intercrystalline Corrosion in the 18/8 Stainless Steels, O. Masi, A. Ferri—pp. 125-128, 140.

Polarographic Continuous Control of the Kinetics of Corrosion, L. Riccoboni, P. Papoff, V. Genta—pp. 129, 144.

Analytical Methods Applied to the Investigation of Potable Waters and of Soil to Determine The Corrosive Power on Ferrous Materials, R. Sandrinelli, P. Brancia, L. Andreini—pp. 130-132.

Laboratory Control of the Corrosive Power of Soil on Steel and Cast Iron Pipes, R. Sandrinelli—pp. 132-135.

Research and Information Sources to Combat Corrosion, M. Pourbaix—pp. 136-140.

Italian Standardization in the Field of "Corrosion of Metallic Materials"—p. 141.

Organization of the Electrolysis Bureau of the Societa Nazionale Metanodotti, A. Grandi—pp. 142-144.

Corrosion Committee of Societa Montecatini and Some Problems Solved by It, E. Hugony—pp. 145-146.

Organization and Activity of Research and Control in the Corrosion Field at the "Breda—Istituto di Ricerche Scientifiche Applicate All Industria," L. Industria, L. Mattboli—pp. 147-148.

Center of Studies for the Marine Corrosion of Metals, M. Raffo—pp. 149-150.

The Bureau of Information on Nickel, Its Activity in the Fight Against Corrosion, C. Galletto—p. 151.

Corrosion Papers Given at ASME Annual Meeting

Papers presented at the November 28-December 3, 1954 annual meeting of the American Society of Mechanical Engineers are as follows:

Chemical Treatment for Corrosion Control by Sheppard T. Powell, consulting engineer, Baltimore, Md., and L. G. von Lossberg, consulting engineer, Baltimore, Md.

Hydrazine for Boiler Feedwater Treatment by Richard C. Harshman, Senior research engineer, Research Department, Olin Mathieson Chemical Corp., Niagara Falls, N. Y., and Eric R. Woodward, supervisor, Market Development Department, Olin Mathieson Chemical Corp., Baltimore, Md.

The Chemical Deaeration of Boiler Water—the Use of Hydrazine Compounds, by Jack Leicester, head of Chemical Engineering Division, Admiralty Materials Laboratory, Dorset, England.

Controlling Iron and Copper Pickup with Neutralizing Amines by Edward A. Yorkgitis, research engineer, Hall Laboratories, Inc., Pittsburgh, Pa., and J. D. Ristroph, chief chemist, Virginia Electric & Power Co., Richmond, Va.

Experiences at Springdale Station Using Various Chemicals as Oxygen Scavengers by M. D. Baker, chief chemist, West Penn Power Co., Springdale, Pa.

Recent Progress in Treatment of Residual Fuels for Gas Turbines by Bruce O. Buckland, manager, Advance and Development Engineering, Gas Turbine Department, General Electric Co., Schenectady, N. Y.

The Evaluation of Corrosion Resistance for Gas Turbine Blade Materials by W. E. Young, research engineer, Charles E. Hussey, design engineer, Steam Division, and Albert E. Hershey, advisory engineer, Research Laboratory, Westinghouse Electric Corp., East Pittsburgh, Pa.

The Influence of Some Chemical and Physical Factors on the Formation of Deposits from Residual Fuels by Peter T. Sulzer, research engineer, Sulzer Brothers, Ltd., Winterthur, Switzerland.

Grace Gets AIChE Award

H. P. Grace, E. I. duPont de Nemours & Co., Inc., Wilmington, Del., was named to receive the 1954 Junior Award in chemical engineering during the American Institute of Chemical Engineers banquet held at the Hotel Statler in New York City on December 14.

Ordinarily preprint copies of papers presented at NACE meetings are not prepared by the association.

Petroleum Industry Nondestructive Testing Methods Reviewed*

By F. A. PRANGE*

Most nondestructive testing methods used in the petroleum industry are quite commonplace but no less useful on that account. Visual examination is used most, although because of its qualitative nature it can hardly serve as a reference method.

The purpose of this article is to enumerate significant procedures and to some extent assess their importance. For the most part, practices mentioned are from experience.

Inspection in the petroleum industry, particularly in refineries has two main ends—to maintain safety of equipment and process continuity. These functions are not alike. Thickness of vessel shells is a prime factor in safety and in conforming to various codes and insurance requirements which generally are quite explicit. Standards on aspects such as weld quality and cracking cannot be spelled out so simply and more is left to interpretation by the inspector. The second viewpoint, that of inspecting and testing to maintain process continuity is less concerned with average metal thickness and more with leaks, cracks and other phenomena. The inspection method

used in each case thus will vary with objective.

Visual Method Valuable

Most valuable nondestructive testing method used in the oil industry is visual examination. One major advantage of this method is that it allows the inspector to cover a considerable area in a short time. Much refinery equipment could not conceivably be checked in any other way.

To illustrate this, take in to account the fact that a fair proportion of pressure equipment in refineries is composed of towers containing bubble caps, chimneys, weirs and down-comers. Visual examination and pit depth measurements are most practical for checking this type of equipment. Simple visual examination often will show cracking or thinning which demonstrates a pattern of corrosive attack. Of course, these visual indications of attack frequently must be checked more thoroughly by other means.

Visual observation assumes many forms. Oil well tubing often is checked by directing sunlight into a tube with a mirror. Other tubing is often inspected by arranging a light bulb in one end and observing irregularities thereby outlined from the other end. Pitting and blistering are discovered easily with very oblique lighting.

Mechanical Calipers Useful

Because this is an electronic age it may seem an anachronism to picture the typical refinery equipment inspector with a bulky mechanical caliper over his shoulder. Nevertheless, thickness measurements made with mechanical calipers are widely used as a nondestructive method of testing in oil refineries. Exposed piping and furnace tubing are calipered when a unit is down for inspection and measurements are carefully recorded and referenced in extensive files. Pressure vessels are checked at nozzle locations only, though pipe often is cut for better coverage. Calipering in this way is accurate and reproducible but coverage is poor because of the limited area available for measurements. Calipering of vessels gives quantitative figures which are much desired.

Oil Well Tubing Calipers

Another widely used form of mechanical caliper is the oil well caliper. There are two main types—one records deviations in internal diameter on a metal chart enclosed in a tubular element lowered into the well and the other, through an electrical circuit, records at the surface movement of feelers exploring the tubing bore. The first type is used in high-pressure condensate well tubing to indicate general thinning, pitting and ringworm corrosion. The electrical type is used generally in tubing of pumping wells to indicate general corrosion and box wear caused by couplings of the sucker rod string rubbing the surface of tubing.

The mechanical type gives more detailed record than electrical type and accurately records progress of corrosion in the well. Both types are compact so that they may be operated inside two-inch tubing. Deposits in tubing are a major obstacle in obtaining thoroughly reliable indications. Intelligently interpreted, these continuous records give a

reasonably good picture of condition of tubing.

Pit Depth Gage Widely Used

Very often corrosion in pressure vessels results in pitting rather than general corrosion. Pitting does not reduce pressure rating drastically but can lead to early leaks. The pit depth gage and its variations are widely used for measuring this type of attack. Frequently only pitting measurements are required to evaluate corrosion if there is enough original surface present to furnish a datum plane. Occasionally a plug of stainless steel is used as datum plane for corrosion measurements. Pitting may be caused by concentration cell pitting, by corrosion-erosion or by localized attack resulting from dissimilar metal combinations such as weld metal and base metal.

Sonic Method Is Speedy

The Audigage is used extensively to supplement and to substitute for other methods of measuring wall thicknesses. This procedure has the advantage of speed, general coverage, small amount of surface preparation required and measurements that can be made almost any place on a vessel instead of at nozzles only. If temperature is low enough thickness measurements can be made while equipment is in operation. In one unit, for example, use of the Audigage to pinpoint sections needing replacement while the piping was still on stream allowed use of carbon steel instead of 12 chrome steel.

The instrument is especially effective when inside surface of the vessel is available for inspection because thin spots located visually can be selected for exact measurement. Disadvantages of the Audigage are that not every man can use it because the operator must be patient, careful and observant in order to get maximum value from the unit and also because it gives unequivocal readings only if the surface is fairly smooth. While pitting, laminations and blisters can be detected by skilled operators indications are only semi-quantitative.

Penetron Is Helpful Aid

The Penetron may be used to supplement the Audigage. It is a radiation-emitting instrument that measures reflected or transmitted radiation used when the surface is too rough for the Audigage or the wall is too thin, surface too hot or it is necessary to scan long lengths of tubing.

This unit is valuable for checking furnace tubing for thin spots and catalytic cracking unit lift pipes while metal is at operating temperature. Values indicated on the Penetron are dependent on fluid in the equipment and sludge or corrosion product near the surface being checked because the reading on the instrument is a function of the mass of fluid in the path of the radiation. Also, the operator must be alert in order to obtain meaningful data. Because the instrument is an integrating device the reading is average wall thickness over a small area and therefore the indicated value does not accurately represent minimum wall at the base of a pit. However, strength of a vessel is more dependent on the average wall thickness than on

(Continued on Page 97)

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Petroleum Industry —

(Continued From Page 96)

the wall remaining at a pit. Thus the Penetron evaluates safety.

Hammer Test Commonly Used

Another method of measuring thickness is by hammer testing. There may be some dispute as to this being a non-destructive test but if the hammer does not make a hole, integrity of the unit is not generally impaired. Hammer testing is widely used on furnace tubes and bends and on pipe in which excessive corrosion may occur. Furnace tubes can be damaged by this type of testing if their insides have been carburized. Hammer testing frequently is used on cooling tower laterals because only the good pipe need be separated from the old material. Retiring junk equipment by hammer testing is quite effective because a hole quickly identifies equipment as junk.

Magnetic Particle Inspection

Reduction of wall thickness is not the only type of damage. Stress corrosion cracking, embrittlement cracking, weld cracking and general defects can also be serious. Magnetic particle inspection is the most widely used method for detecting these conditions. It is used to detect corrosion fatigue cracks in the body of drill pipe and cracks at threads of joints.

Fluorescent magnetic particle inspection is a variant of the procedure. Magnetic particle inspection is used in later life of a well to determine the condition of sucker rods. Further inspection may be done for fatigue cracks in pumps, engines and compressors or in plant piping.

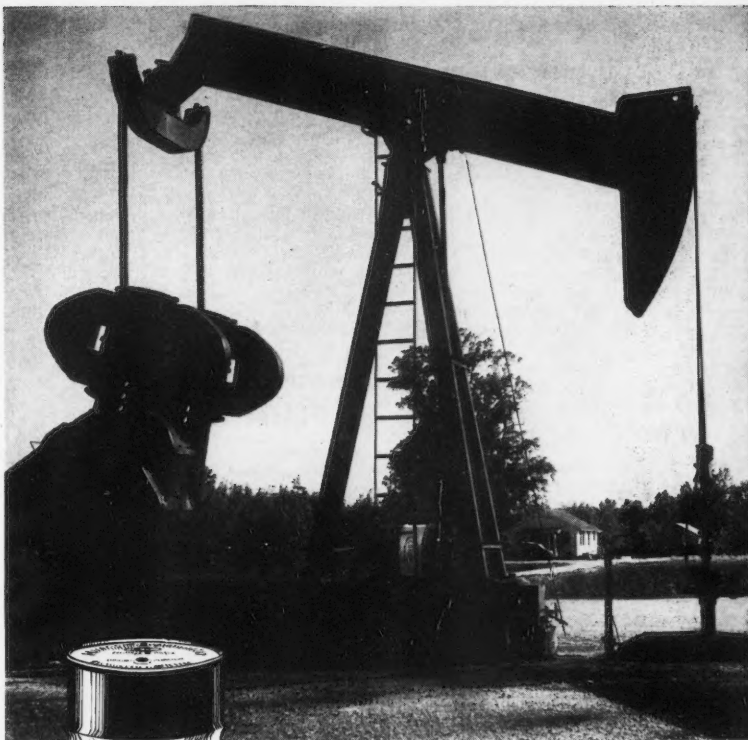
In refineries or gasoline plants this method is used to detect stress corrosion cracking in amine gas treaters, in vessels handling caustic and to check for cracking caused by hydrogen embrittlement encountered in hydrogen sulfide or hydrofluoric acid environments. As a routine tool it is used to check weld quality.

Test Holes Are Expensive

Drilling test holes to obtain direct measurements of wall thickness of vessels and piping is similar to use of pit depth gages and calipers. If drilling is from the corroded surface at selected points it gives excellent results. However, if it is from the uncorroded surface thickness evaluations are no more accurate than those of several other methods mentioned. Obviously drilling and plugging test holes is expensive and not really nondestructive but it is at least an alternate to other nondestructive methods.

Telltale holes to indicate excessive corrosion are used extensively by the petroleum industry. In practice these holes are about $\frac{1}{8}$ inch in diameter and drilled to a depth corresponding to minimum thickness allowed on equipment. When corrosive attack thins metal at this point a small leak results, giving the operator warning that the equipment needs repair or replacement. Equipment may be run for a short time after the warning leak develops by plugging the hole. Valves sometimes are used over these telltale holes so that leaks may be shut off easily. Telltale holes thus are a sort of "go or no-go" gage that indicates structural soundness of unit.

(Continued on Page 98)



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Technical Aids for Small Business is a publication issued by the Small Business Administration, U. S. Government. Free copies are available from field offices of Small Defense Plants Administration or U. S. Chamber of Commerce.

The following are some of the aids which have been published:

August 1952: No. 8, Metallizing, by Joseph de Feher, provides information on metallizing including advantages, techniques, major uses and miscellaneous uses. Bibliography TA8B providing more complete information on metallizing is available free from Management Service Division, Office of Production and Management Assistance, Small Defense Plants Administration, 1337 E. St., N.W., Washington 25, D. C.

November 1952: No. 14, Corrosion in Machine Shops—Causes and Prevention, by Joseph de Feher, gives information on corrosion including causes of, rustproofing and preliminary steps, preventing corrosion in aluminum workpieces, rustproofing steel workpieces, preventing corrosion or oxidation of copper and brass, protection with plastics, final coating and protecting equipment and machinery against corrosion. Bibliography TA 14B listing source of reliable information on phases of corrosion-prevention in machine shops is available free from Managerial Assistance Division, Small Business Administration, 811 Vermont Ave., N.W., Washington 25, D. C.

September 1953: No. 18, Surface Cleaning Techniques—I, by Joseph de Feher, provides information on surface cleaning including cleaning techniques, surface conditioning of various steels, precleaning copper alloy surfaces, surface conditioning of stainless steel, conditioning nickel alloy workpieces, preconditioning aluminum surfaces, cleansing magnesium castings, alkaline cleaning, solvent cleaning, cleaning with spirits of petroleum, acid pickling, electrolytic pickling and ultrasonic cleaning. Bibliography TA 18 B providing a discussion of improvements in surface precleaning techniques and related equipment is available free from Management Service Division, Small Business Administration, Washington 25, D. C.

March 1953: No. 21, Surface Finishing Techniques, contains information on final finishing including improved surface finishes on steel, plating on steel, galvanizing, painting, finishing iron castings, bright zinc electroplating and tinning steel. Bibliography TA 21B listing sources of additional data on various operations of final finishing is available free from Management Service Division, Small Defense Plants Administration, Washington 25, D. C.

April 1953: No. 22, Surface Finishing Techniques—II, by Joseph de Feher, contains information on surface finishing process including mechanical processes, polishing, cleaning, electroplating and chemical polishing, as well as on final surface finishing processes such as coatings, plating, painting and lacquering, frosted finishes and proprietary finishes. A bibliography providing additional information is available free from Management Service Division, Small Business Administration, Washington 25, D. C.

May 1953: No. 24, Surface Finishing Techniques—III, by Joseph de Feher, provides information on economical finishing of magnesium and copper alloys and stainless steel workpieces. Bibliography TA 24 B

containing new developments taking place in surface finishing which affect operations in machine shop working on simplest or complicated workpieces is available free from Management Service Division, Small Business Administration, Washington 25, D. C.

August 1953: No. 29, Inventions: Government-Owned; Government-Licensed and Registered for License or Sale, by J. Wade Rice, describes four groups of inventions and patents which are government-owned, government-licensed, registered privately-owned patents or dedicated patents. Copies of patents issued on these inventions may be purchased for 25c each from the Patent Office, U. S. Department of Commerce, Washington 25, D. C.

Abrasion Tester Developed By PEI at NBS

Development of an abrasion tester to provide accurate and uniform measurement of abrasion resistance of a surface regardless of degree of smoothness of surface is announced by the Porcelain Enamel Institute. Tester was developed by PEI's Research Fellowship at the National Bureau of Standards under guidance of institute's Quality Development Committee.

Unit consists of a motor-driven table which gyrates in a horizontal plane at frequency of 300 rpm with each point on table describing a circle $\frac{7}{8}$ inch in diameter. The canvas-base Bakelite table is driven by a $\frac{1}{4}$ hp motor. A specimen is placed in any one or more of nine positions and secured by means of rubber coated aluminum retaining ring. Abrasive charge is added through hole in top of retaining ring.

Degree of abrasion resistance for porcelain enamels has been evaluated in terms of weight loss and gloss loss and wear of less resistant materials can be evaluated in terms of thickness loss, the institute reports.

Further information about the tester may be obtained from the Porcelain Enamel Institute, 1346 Connecticut Ave., N.W., Washington 6, D. C.

Paint and Varnish Clubs Elect Newell P. Beckwith

Newell P. Beckwith was elected president of the Federation of Paint and Varnish Production Clubs at the association's November meeting in Chicago. He succeeds Calvin J. Overmyer, last year's president.

Mr. Beckwith is vice-president and technical director of Rinshed-Mason Co., Detroit, Mich. and also is vice-president and general manager of Rinshed-Mason Co. of Canada, Ltd. In 1952, at the invitation of the Belgian government, he conducted a productivity survey of the paint industry in Belgium for the purpose of advising means of making improvements. He served with the Army Ground Forces during World War II and was discharged as a lieutenant colonel.

Aircraft Components Glued

Development of high strength resin and resin-rubber adhesives has made possible the bonding of all-metal aircraft structural components.

Investigations conducted by the National Bureau of Standards under sponsorship of the National Advisory Committee for Aeronautics and the Navy Bureau of Aeronautics

indicate mechanical properties of bonded panels are comparable to riveted panels but that such factors as humidity, pressure and temperature in fabricating process can produce imperfections which greatly decrease strength of joint and often can be detected only by destructive tests.

Petroleum Industry—

(Continued From Page 97)

Holes must be drilled and gaged by competent personnel or drilling may be too deep, resulting in premature shut-downs or contrariwise drilling may be so shallow that integrity of the vessel or tube is threatened before a warning is given. Test holes are used extensively on furnace tubing and vessels exposed to severely corrosive environments. In general, ultrasonic testing is favored over this method because of cost and leaks resulting from holes drilled too deep.

Fluorescent Dye Method

Fluorescent or colored penetrating dyes are reliable to outline cracks and weld defects. These dyes locate very tight cracks sometimes not found even by magnetic particle inspection. They are particularly useful in finding cracks in threaded sections. Although sometimes used in the field because careful work is required they are most often employed in repair shops.

From the preceding discussion it might seem that the petroleum industry is adequately supplied with nondestructive testing instruments. However, inspection of the interior of tubular goods provides a field to be explored. There are hosts of defects and types of corrosion damage that need to be detected. New tubes have seams, plug cores, mandrel marks and bursts and as a result of service there are induced corrosion fatigue cracks, pitting, ringworm corrosion and corrosion-erosion. Because they are on the inside the various defects are very difficult to evaluate quantitatively.

Telescopes and Probolog

The tube-telescope and the Probolog are used in internal inspection but leave something to be desired. The tube-telescope occasionally is used to supplement internal inspection of drill pipe with the various magnetic particle tests. This optical instrument is slow and results qualitative only. The Probolog is an eddy-current device used to detect various forms of discontinuities in the wall of nonmagnetic tubing. It indicates these discontinuities but does not identify them or fully measure the extent of damage unless there is only one kind of attack present.

Film Thickness Gages

Magnetic and electro-magnetic film thickness gages are used to measure paint and protective coatings. Electric strain gages are used to evaluate pressure ratings of peculiarly shaped vessels or to rate flanges and reinforcements. Whitewash and brittle lacquer are used for the same purposes. Radiographic inspection is occasionally made of pressure equipment subject to corrosion as in the case of Christmas trees for high pressure condensate wells. Both the Reflectoscope and radiographic equipment are used in checking weld quality on vessels. Obviously only a few of these last named methods and instruments are likely to be used on routine tools.



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NEW PRODUCTS — Materials — Service — Literature

A Co-Axial Disc Type cell and valve assembly for detecting salt content and other impurities in fluids is produced by McNab, Inc., 225 Lafayette St., New York City, for use with McNab Salinity Indicators for measuring impurities of fluid in excess of desired preset values so preventive steps against corrosion or contamination may be taken. Manufacturer claim no fluid escapes to scald or burn operator as cell is inserted or removed from liquid because valve cannot be opened unless cell is fully seated and cell cannot be removed when valve is open. Valve utilizes O-ring seals which are said to eliminate need for lapped surfaces often damaged by insertion of cell unit resulting in leakage.

Alcoa Ribbed Industrial Siding is being marketed by Aluminum Company of America, 745 Alcoa Bldg., Pittsburgh 19, Pa. The siding has good resistance to atmospheric corrosion, and retains its tensile strength well. The company is also selling newly designed roofing accessories, featuring an extruded gravel stop, combining cant strip and fascia band. Test data and other information can be had by writing for the illustrated brochures.

Centre Belge D'Etude De La Corrosion, 21 rue des Drapiers, Bruxelles, Belgium, has distributed a list of 17 technical publications, giving prices for each.

Protection of Steel and its alloys from both chemical and elevated temperature corrosion can now be accomplished by metallurgically bonding pure aluminum and its alloys to the ferrous materials, according to the Arthur Tickle Engineering Works, Inc., 21 Delavan St., Brooklyn, N.Y. The parts are fluxed in a salt bath, then immersed in molten aluminum for a few minutes to produce a metallurgical iron-aluminum alloy bond at the interface.

The Sel-Rec filter, manufactured by the Bart-Messing Corp., 229 Main St., Belleville 9, N.J., gives double the filtering area and volume in the same space required by present filters on the market. The filter can be used with either a new type stainless steel element or standard porous stone elements.

Protection Against Corrosion in the air conditioning system of the Cleveland, Ohio Public Auditorium was gained in part by use of more than 50 tons of wrought iron pipe in service lines, according to the A. M. Byers Co. The piping, ranging from one-half inch to 12 inches is installed in chilled water lines, cooling water lines, water piping, and waste and vents.

A Portable Stress Analyzer using the X-ray diffraction method is now available for field and plant operations, according to Holger Andreasen, Inc., 703 Market St., San Francisco 3, Calif. Known as the Androscope, it measures the magnitude and sense of residual stress in metals, plastics and other materials.

Camac Acid Proof Plastic Jet Siphons for emptying waste acid from tanks and sumps are manufactured by Carl Buck & Associates, Essex Fells, N. J. The siphon is not attacked by acid or alkaline solutions except strong chromic or nitric acid. Nozzles are sized for standard acid hose. Two capacity sizes are available, 1200 gph and 4000 gph. Steam pressures range from 10 psi to 50 psi.

Superduct, a new heavy-duty rigid steel electrical conduit especially designed for service in very severe corrosive atmospheres has been developed by National Electric Products Corp., Gateway Center, Pittsburgh, Pa. The new conduit better withstands the attacks of sulfuric acid, caustic lye, salt spray and heat in comparison with other types of corrosion-resistant conduit. Results of tests available.

Proseal D-36, a new chromate treatment for hot dip galvanized surfaces, is said to give good resistance to the formation of white corrosion products without discoloring galvanized surfaces. For further information write Promat Division, Poor & Company, 851 S. Market St., Waukegan, Ill.

Five Tips on Lubricating Your Plug Valves, a brief summary of valve care is published by the Rockwell Manufacturing Co., 400 N. Lexington Ave., Pittsburgh 8, Pa.

Five-Page Technical Bulletin No. 2 published by Haveg Corp., a subsidiary of Continental-Diamond Fibre Co., Newark, Delaware, describes Haveg 4310 Cement (Phenolic). Company claims cement has outstanding ability to resist deteriorating effect of high temperature and to withstand chemical attack by variety of corrosive materials. Bulletin includes table and ratings as guide for use of the cement.

An Eight-Page Booklet (G-21), "1955 Guide to Improved Packaging With Bakelite Plastics and Resins" is available from Bakelite Co., a division of Union Carbide and Carbon Corp., 300 Madison Ave., New York 17, N.Y. Booklet provides information on wide range of materials including Bakelite polyethylene, phenolic, styrene, C-11 and vinyl plastics and resins. Ease and economy of fabrication are demonstrated through applications of molded and blown plastics, coatings, adhesives, film and rigid sheet materials in packaging and display.

Technical data on Dur-Ace, a general-purpose, corrosion-resistant plastic pipe are provided in five-page Bulletin 80-A published by American Hard Rubber Co., 93 Worth St., New York 13, N.Y., producers of the pipe. Bulletin includes information on general properties of multi-polymer rigid plastic pipe and chemical resistance tables, standard sizes, pressures, prices of pipe, fittings and diaphragm valves as well as installation and fabrication data.

Crawford Fitting Co., 884 E. 140th St., Cleveland 10, Ohio, produces two grades of thread lubricant for use on titanium, stainless steel and aluminum. Blue Goop for temperatures up to 400 degrees F eliminates galling so threads may be re-used and Silver Goop available for temperatures up to 2100 degrees F is effective antiseize compound for use on threaded parts of stainless steel and high temperature alloys, the company says.

Technic, Inc., Providence, R. I., has issued a data sheet on electroplated palladium and electroplated platinum. Sheet describes physical properties from atomic weight to reflectivity and electrical properties from resistivity to specific magnetic susceptibility. Corrosion resistance is detailed as well as hardness of electroplated, electroplating specifications and thickness requirements. Copy of data sheet and data sheet on Electroplated Gold and Electroplated Rhodium are available from the company.

A Four-Page listing of isotope compounds available from Bio-Rad Laboratories, 800 Delaware St., Berkeley, Cal., has been published by the company. Pamphlet provides alphabetical index of compounds including alternate nomenclature and index numbers in chemical classification list.

Eco Synthetic Rubber pump is available with Hastelloy-B or Hastelloy-C shaft, eccentrics and guides. Eco Engineering Co., Newark, N. J., manufacturers of pump claim Hastelloy-B permits handling of boiling hydrochloric, sulfuric and mixed acids and Hastelloy-C extends pump service to highly oxidizing acids and such oxidizing agents as free chlorine and bleaching compounds. Manufacturer reports pump is positive displacement, oscillating, rotary type designed for quiet, turbulence-free pumping of chlorine bearing fluids, acids, alkalis and variety of organic and inorganic chemicals compatible with its synthetic rubber body. Capacities of 10 gpm and pressures of 100 psi are realized at sustained 1725 rpm the company says.

A Brochure Describing "Alumi-Coat" process of bonding aluminum and its alloys to ferrous metals is available from Arthur Tickle Engineering Works, Inc., 21 Delavan St., Brooklyn 31, N.Y.

Fifteen-Page Issue of Newscast published by Cooper Alloy Corp., Hillside, N. J., deals with company's stainless steel castings, valves and fittings. Publication provides information on cast stainless alloys, designing for sound castings in stainless steels, shell molding and factors in designing cast-weld construction. Charts include information on properties of cast stainless steel, Cooper alloy designations and application of Cooper alloys with remarks. Copies are available from the company on request.

(Continued on Page 102)

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NEW PRODUCTS

(Continued From Page 100)

Bruhin's Rust & Scale Solvent for rust, scale, lime and corrosion is said to remove these deposits from metal and other surfaces and at the same time strip light oil, grease and dirt film. Bruhin & Co., Inc., 2939 Columbia Ave., Indianapolis 7, Indiana, manufacturers of the solvent, claim it will etch and neutralize alkali of fresh concrete, thereby giving good adhesion for concrete paint.

Paraclone, a mechanical dust collector produced by Aerodyne Corp., 1520 Lakeside Ave., Cleveland, Ohio, is said to differ from conventional systems embodying large number of small cyclones in parallel by having a secondary circuit which keeps discharge from small cyclones under constant negative pressure thus preventing recycling of dust in primary system. Manufacturer claims small cyclones which are cast from an abrasion-resistant grey iron are highly resistant to wear in handling abrasive particles.

Bulletin 55G showing major stainless steel gate valves in Cooper Alloy line is available from Cooper Alloy Foundry Co., Hillside, N. J.

Spinco Analytrol, a null or unbalanced device utilizing system of two barrier-layer photocells illuminated from a single light source is produced by Specialized Instruments Corp., 700 O'Neill Ave., Belmont, Cal. Manufacturer claims device simultaneously produces component distribution curve and accompanying sawtooth totalizing curve as variable density strip, such as paper electrophoresis pattern, is automatically drawn through scanning mechanisms. Alternatively, automatic totalizing curve can be produced from any existing distribution curve by manual following of original curve, the company says. Auxiliary mechanisms are available to permit operation with ultraviolet rather than visible light and to adapt for colorimetric recording of stationary or moving fluids in tubes. Material to be scanned is passed before one of the cells causing output current drop and unbalancing of bridge circuit. Unbalanced signal is amplified and used to drive motor which interposes light-shielding cam in front of other photocell until balance is restored. Same mechanism drives curve-drawing and integration pens. Because of light-shielding cam principle various mathematical functions can be introduced to accommodate differences in response between optical density and actual concentration of material, the company reports.

Carboline Co., 331 Thornton Ave., St. Louis, Mo., produces Neoprene No. 750 Sheet Lining which it says shows maximum abrasion resistance, protection against acid and alkali corrosion and economical application. Lining is recommended for coal bunkers, agitating and mixing equipment and coal and gravel chutes.

Windtrol, an automatic control device for regulating industrial air pollution is produced by Friez Instrument Division of Bendix Aviation Corp. Device is said to activate equipment only when wind speed and direction result in objectionable pollution situation.

An Atomic Battery said to be about the size of a cigaret lighter has been developed by the Atomic Energy Commission. Battery consists of small capsule containing $\frac{1}{4000}$ ounce of radioactive polonium which is converted into electricity by a series of thermo-couples. It is too costly for commercial production the AEC says.

Edison "MC," a battery with all structural cell parts made of nickel or nickel plated steel is produced by Edison Storage Battery Division of Thomas A. Edison, Inc., West Orange, N. J. Manufacturer claims battery adds 25 percent more power, will fit into battery box made for "C" type battery and design does not deviate from standard steel tube and pocket construction. Negative tubes are identical with those employed in C-type cells and positive tubes are slightly shorter. Positive tubes contain flakes of pure nickel alternated with layers of nickel hydrate and negative pockets contain iron. Electrolyte is solution of caustic potash plus small percentage of lithium hydrate in distilled water. Company reports nickel is used because it improves conductivity and resists corrosion and contamination during fabrication and storage and because it resists corrosion in industrial atmospheres where battery is used.

PERSONALS

Otto J. Blank, vice-president of R. M. Hollingshead Corp. will direct the company's newly-created development and expansion program.

John B. Moore, Corp., P. O. Box 3, Nutley 10, N. J., has selected **Irving Q. Sarling** to fill a vacancy on the board until regular stockholders' election in 1955. Mr. Sarling is the company's process engineer. The company has also appointed four technical service and sales representatives. They are **Charles C. Searles** for the Northern Illinois area, **Charles H. Cadiz** for Delaware, Maryland, District of Columbia and Virginia area, **William I. Lightfoot** for Kentucky and Tennessee area and **Industrial Equipment Company** for the five-state Central West area.

M. C. Crockett has been appointed automotive industry manager of Kaiser Aluminum & Chemical Sales, Inc. Mr. Crockett will retain his position as Detroit district manager of the company.

Harold C. Jenseth has been appointed plant manager of the San Francisco plant of Distribution Assemblies Department, General Electric Co.

M. A. Burello, formerly with market research and sales promotion department of E. I. du Pont de Nemours & Co., Inc., has joined the product planning group of Carboloy Department, General Electric Co., Detroit 32, Mich.

Marshall B. Taft has been named general manager of the valve division of Minneapolis-Honeywell Regulator Company. He succeeds **Stephen A. Keller** who has been named general manager of the company's Heiland division in Denver.

Eric Ruckelshaus has joined Ebasco

Services, Inc., as senior business consultant. **Lee Hanower** has been assigned as business analyst in the company's petroleum and plastics fields.

Walter E. Schott, Jr. has been named salesmanager of Pipe Line Anode Corp., Tulsa.

Marshall Hyde has been named distributor in the Michigan area and **Ben A. Hughes, A. F. "Gus" Vogler** and **D. E. Hughes** have been named respectively office manager, sales engineer and district representative at Houston by Pipeline Coating and Engineering Co., Inc.

C. G. Stupp, technical director for Barrett Division, Allied Chemical and Dye Corp., New York, has been appointed a vice president of his firm.

Edwin Verecke has been promoted to the position of executive vice president of Heil Process Equipment Corp., Cleveland.

Bennett S. Ellefson has been appointed technical director of Sylvania Electric Products Inc., 1740 Broadway, New York 19, N. Y.

James P. Haight has been named chief engineer of Aluminum Company of America, Pittsburgh 19, Pa. **John L. Patterson** succeeds Mr. Haight as general manager of the company's fabrication division.

Kenneth G. Carroll has been named head of the Physics Section, Bayonne Research Laboratory of The International Nickel Company, Inc., New York 5, N. Y.

Y. Iwamura has been elected president of Tokyo Coke Co., Ltd., 3, 1-chome, Yaesu Chuo-ku, Tokyo. Mr. Iwamura continues as director of Tokyo Gas Co.

Wilson F. Marks has been appointed product manager of Cold Applied Coatings Section, Tar Products Division of Koppers Co., Inc., Pittsburgh 19, Pa.

P. S. Hoffman, Jr., has been elected vice president in charge of manufacturing of Donegal Manufacturing Corp., Marietta, Pa.

R. M. Hollingshead Corp., has appointed **Harold L. Danziger** group manager in charge of the organization's Automotive, Special Brands and Universal divisions.

Ray E. Fleeson has been appointed to sales staff of Chicago district, Tubular Products Division of The Babcock & Wilcox Co., 161 E. 42nd St., New York City.

John A. Howsmon has been named leader of the Acetate Section in the Research and Development Division at American Viscose Corporation's Marcus Hook, Pa., research center.

Matthew B. Riordan has been named vice president in charge of engineering, research and development of BJ Service, Inc., a subsidiary of Byron Jackson Co., Los Angeles 54, Cal.

Joseph G. Surcek has been appointed senior research leader of Rust and Preventives, Dearborn Chemical Co., Merchandise Mart Plaza, Chicago 54, Ill.



Corrosion Abstracts

INDEX TO CORROSION ABSTRACTS

Vol. 11	January, 1955	No. 1
		Page
1. GENERAL		
1.5 Directories of Material		103
2. TESTING		
2.1 General		103
2.3 Laboratory Methods and Tests		103
2.4 Instrumentation		104
3. CHARACTERISTIC CORROSION PHENOMENA		
3.2 Forms		104
3.5 Physical and Mechanical Effects		104
3.7 Metallurgical Effects		105
3.8 Miscellaneous Principles		106
4. CORROSIVE ENVIRONMENTS		
4.3 Chemicals, Inorganic		106
4.5 Soil		106
4.6 Water and Steam		106
4.7 Molten Metals		107
6. MATERIALS OF CONSTRUCTION		
6.3 Non-Ferrous Metals and Alloys—Heavy		108
6.4 Non-Ferrous Metals and Alloys—Light		110
6.6 Non-Metallic Materials		111
7. EQUIPMENT		
7.1 Engines, Bearings, and Turbines		112

1. GENERAL

1.5 Directories of Material

1.5, 1.6, 8.8.1

Corrosion Data Survey. G. A. NELSON. Book, 1954, 66 pp. Shell Development Company, Emeryville, Cal. Per copy \$35.00.

Effects of corrosives against materials of construction in chemical plants have been collected into usable form. Principal content is 60 corrosion data charts measuring 15 by 10 inches in which the corrosion characteristics of the materials considered are recorded.

The 28 materials considered are used as the horizontal ordinate of the charts, while an alphabetical list of corrosive materials comprises the vertical ordinate. The intersection of the ordinates consists of an area ruled into 100 squares. This permits the recording of the following information: 1) concentration in aqueous solutions and ratings for dry materials; 2) temperatures in 50 degree increments from 75° to 300° F and up to 800° in 100 degree increments. Higher temperature data is also indicated when significant; 3) four ratings of corrosion based on dimensional loss per year. Information on velocities, impurities, aeration, surface condition and galvanic effects is added in small notes to the graphs. Small notes also have been added on factors related to fabrication and heat treatment but inhibitors are not considered.

The data presented are suggested to

permit rapid elimination of unsuitable materials but are not recommended as a final basis of choice in every instance. A column devoted to special alloys includes ratings of materials such as zirconium, titanium, Stellite, Illium G, Chlorimet, and others. Non-metallics considered include Havel, Saran, Teflon and Karbate. The final series of charts considers corrosion of materials by sulfuric, hydrochloric, mixed acids, hydrogen and carbon monoxide with the ordinates respectively temperature and concentration in percent. Area effects indicate the data. The book concludes with a section devoted to the comments of research laboratories to which copies of the earlier book (1950) were sent. 7573

2. TESTING

2.1 General

2.1.1, 5.9.4

Evaluation of Several Sets of Constants and Several Sources of Variability. V. W. VAURIO AND C. DANIEL. *Chem. Eng. Progress*, 50, No. 2, 81-86 (1954) Feb.

Test designed to establish sources of variation in prune-pack results is described for tin-plate corrosion-resistance investigations.

Basic statistical principles are applied to experiment designed to study simultaneous impact of considerable number of factors; principle of balance is emphasized because it permits conclusions of maximum generality and because all data can be used in drawing each conclusion, giving results of maximum precision; application illustrated in studies of effect of four pickling treatments on corrosion resistance. Tables, diagrams, 8 references. 7657

2.3 Laboratory Methods and Tests

2.3.6, 2.6

Electron Microscopic Investigation of Metal Surfaces with Silicon-Monoxide Replicas. HEINZ WISLORF. *Z. Metallkunde*, 45, No. 1, 14-22 (1954) Jan.

In replica methods thin films (a few Å) are formed on the metal which show the surface relief in its original form. A direct replica method has been developed in which, in a vacuum apparatus, silicon monoxide is evaporated at an angle of 90° on the surface of the investigated metal. The formed film is electrochemically or mechanically removed from the surface and shadowed. Silicon-monoxide films show good mechanical qualities which makes it possible to cover slits of 1 × 0.1 mm. This produces a large field of vision. Further advantages are: high electron transmissibility which allow the use of comparatively thick replicas; amorphous structure which eliminates limitation of the solution by crystal reflections—a solu-

tion as low as 36 Å is possible; chemical resistance which makes possible the use of aqua regia for detaching the films. It is possible to reproduce rough surfaces. Among the practical applications described are surface investigations on electropolished aluminum, investigation of cross slip and deformation bands after plastic deformation of aluminum and the study of grain boundaries in stretched high purity aluminum.—A.I.J. 7601

2.3.7

A Tension Impact Test for Sheet Metals. C. W. MUHLBRUCH. North-western Technological Inst. Paper before Am. Soc. Testing Materials, 56th Ann. Mtg., June 28-July 3, 1953. *ASTM Bull.*, No. 196, 43-49; disc. 49-50 (1954) Feb.

Discusses test specimens and fittings developed to determine the impact strength of stainless steel and low-alloy steel sheet metals up to 0.125 in. thick. Method of machining the fittings and specimens as well as permissible tolerances for satisfactory test results are reported. 2 types of fittings and test specimens are described, one for the determination of basic fracture toughness values and the other for an evaluation of notch sensitivity. Test data are reported for a number of materials. Illustrations.—INCO. 7580

2.3.7, 5.3.2

The B.N.F. Jet-Test on Organic Bright Nickel Deposits. J. EDWARDS. Paper before Inst. of Metal Finishing, London, Sept. 21, 1953. *Bull. Inst. Metal Finishing*, 4, No. 1, 33-46 (1946) Spring.

The rate of penetration of organic bright nickel deposits in the B.N.F. jet test is shown to vary with thickness of deposit. Therefore it is necessary to use a calibration curve relating apparent and true thickness. Although minor variations in plating conditions have little effect, separate calibration curves are required for deposits from different proprietary solutions and there is some evidence that differences can arise between individual baths of nominally the same type. Unless the calibration can be checked on deposits from a given bath, it is recommended that the jet test on organic bright nickel deposits be used primarily as an acceptance test of the "limit" type.—INCO. 7635

2.3.7, 5.3.2

Determination of Thickness of Thin Nickel Coatings on Iron by Means of Stripping Process. G. SCHIKORR. *Metall-oberfläche*, 8, B49-B51 (1954) April.

Data relating to attack on basis metal. In considering effects of anodic sulfuric acid treatment results prove unfavorable. Description is given of process involving fuming nitric acid with 5% chromic acid as rinsing medium. Comparison is made with results obtained using a solution of sodium cyanide, ammonium persulfate and distilled water. Description of, and results obtained with, anodic process for stripping nickel coatings from copper (involves sulfuric

acid) and results using nitric acid and solution containing $\text{NaCN} + (\text{NH}_4)_2\text{S}_2\text{O}_8 + \text{H}_2\text{O}$ (both unsatisfactory) are given. Recommended procedures are anodic treatment in sulfuric acid for removal of nickel, followed by treatment in fuming nitric acid or ammonium solutions for stripping of copper. Thickness is measured from weight loss values.—INCO. 7577

2.3.9

A Specimen Heater for Electron Diffraction. R. G. PICARD AND E. G. DORN-FELD. Radio Corp. of America. *Rev. Sci. Instruments*, 25, 158-160 (1954) Feb.

An electric specimen heater for diffraction studies at temperatures up to 1500° F is described. Specimens up to 1/2-inch square may be heated by the element which fits in the vacuum chamber upon the regular stage of an RCA-Type EMD-2 diffraction camera. The principal problem is the reduction of stray magnetic fields from heater wires to a negligible value. This is achieved by using low current in high-resistance wire and reverse winding the heater coils. Radiation and conduction losses are cut to a minimum by enclosing the heater element in "LAVA" (hydrous aluminum silicate) except for a window over which the specimen is mounted. D.C. power is taken from the power supply for the valving system.—NSA. 7611

2.4 Instrumentation

2.4.3

The Correlation of the Betatron With Other Forms of Non-Destructive Testing. H. B. NORRIS. *ASTM Bull.*, No. 187, 56-57 (1954).

Increased value of tests such as magnetic particle, ultrasonic and X-ray results when used in conjunction with the betatron.—MR. 7596

2.4.3

Application of Radio-Active Isotopes to Steel Foundry Radiography. L. WILKINSON. *Engineer*, 197, 383-387 (1954) March 12.

Radioactive properties of cobalt 60, tantalum-182 and iridium 192 are largely complementary enabling thicknesses ranging from a 1/2 to 5 in. of steel to be examined with adequate contrast and sensitivity. Tables.—MR. 7602

2.4.3

Application of Cesium 137 to Industrial Radiography. JAMES W. DUTLI AND GROVER M. TAYLOR. *Non-Destructive Testing*, 12, 35-38 (1954) March-April.

Fission-product isotope cesium-137 investigated for use as gamma-ray source for industrial radiography. Diagram, graphs, radiographs, tables, 6 references.—MR. 7632

2.4.3, 7.4.2

Some Unusual Radiographic Problems. M. D. PHILLIPS, M. L. RHOTEN AND CLARA KIMMEL. *Nondestructive Testing*, 12, No. 2, 17-19 (1954) March-April.

Among the problems presented to the X-ray laboratory of Battelle Memorial Institute is the investigation of intergranular corrosion in a cooling unit which is cycled from freezing to thawing four times a minute when in operation. In constructing the units, aluminum is cast around the copper coil and part of the copper is melted into the alumi-

num. There is considerable breakage and corrosion of the units when they are operated. If any moisture gets into the area where copper is in contact with the aluminum, a galvanic action takes place, causing intergranular corrosion. The radiograph shows porosity in the aluminum which is part of the reason for the cracking. Moisture gets into this area, and its alternate freezing and thawing produces the cracking. The X-ray equipment used covers the range of voltages from 5 to 250 kv. In addition, the laboratory has a 10-c cobalt 60 source.—ALL. 7613

3. CHARACTERISTIC CORROSION PHENOMENA

3.2 Forms

3.2.3, 3.4.9, 6.5

Adsorption Studies on Metals. Part III. The Sorption of Water Vapor on Nickel, Steel and Molybdenum. A. C. ZETTMAYER AND J. J. CHESSICK. Lehigh University. *J. Phys. Chem.*, 58, No. 3, 242-245 (1954) March.

Study of the oxide films present on the surface of nickel, steel and molybdenum was made using both gas adsorption and calorimetric techniques. Nickel and steel powders degassed at 25° C were found to exhibit only physical adsorption of water vapor, and the heat of emersion in water was about 550 ergs/cm.² for both. Degassing the nickel powder at 300° removed a strongly bound layer of water and raised the heat of emersion to 950 ergs/cm.² Tables, graphs and 10 references.—INCO. 7669

3.2.2, 3.7.2

How Dissolved Nitrogen Affects Graphitization. G. V. SMITH. U. S. Steel Corp. *Iron Age*, 173, No. 15, 136-139 (1954) April 15.

Studies made by U. S. Steel Co. show that nitrogen dissolved in aluminum killed steel inhibits graphitization by combining with residual aluminum. Failure of welded molybdenum steam pipe in service as a result of graphitization started the investigation. Instability of iron carbide is the heart of the graphitization problem. Test results show increased susceptibility to graphitization as the amount of nitrogen decreases. Deoxidation products of aluminum do not appear to serve as nuclei for graphitization. Combine as aluminum nitride. Nitrogen does not affect graphitization. Illustrations, table.—INCO. 7587

3.2.2, 5.4.5

Mechanism of Filiform Corrosion. W. H. SLABAUGH AND M. GROTHEER. Kansas State Coll. Paper before ACS, 124th Mtg., Chicago, Sept. 1953. *Ind. & Eng. Chem.*, 46, No. 5, 1014-1016 (1954) May.

Observations show that underfilm, or filiform, corrosion is an electrochemical process. The actual electropotential that exists between anodic and cathodic areas was measured and the identity of these areas was established. The critical role of humidity and its effect in producing osmotic cells warrants the application of a film which does not serve as a semipermeable, osmotic membrane. Other preventive measures concern the elimination of water-soluble components or extractives in the coating. Presence in

the system of a suitable agent which converts Fe (II) to Fe (III) as soon as it forms would also inhibit filiform corrosion. Diagrams and 5 references.—INCO. 7588

3.2.3, 6.3.10, 3.8.4

The Kinetics of Oxidation of High Purity Nickel. E. A. GULBRANSEN AND K. F. ANDREW. *J. Electrochem. Soc.*, 101, No. 3, 128-140 (1954) March.

The effect of time, temperature, and surface pretreatment on rate of oxidation of high purity nickel is studied for the temperature range of 400°-750° C using a vacuum microbalance technique. The data are compared to previous studies in the literature and with other metals. Oxidation data are interpreted in terms of the parabolic rate law and classical theory of diffusion.

Large deviations from the parabolic rate law are found to occur during the initial stages of reaction and smaller deviations over long periods of time, especially at low temperatures. However, reasonable values of heat and entropy of activation for the over-all reaction can be calculated; these are 41,200 cal/mole and -6.0 entropy units (eu), respectively. Parabolic rate law constants over the temperature range of 550°-700° C are given by

$$A = 3.8 \times 10^{-4} e^{-41,200/RT} \text{ cm}^2/\text{sec.}$$

The negative value for entropy of activation for the over-all reaction when corrected for entropy of formation of the vacancies leads to a value of 1.5 for entropy of activation for diffusion. Theoretical considerations suggest that the latter term should have a value of 1.7-3.3 eu. The good agreement between theoretical and experimental entropies of activation suggests that diffusion is occurring largely through the lattice of nickel oxide and not at grain boundaries, at least for the temperature and time region over which analyses were made.

A comparison of present data with older studies in the literature shows a large variation in parabolic rate law constants. These variations are interpreted in terms of impurities increasing the concentration of nickel ion vacancies. 31 references. 7571

3.5 Physical and Mechanical Effects

3.5.8, 2.3.7, 2.1.1

Statistical Study of Overstressing in Steel. G. E. DIETER, G. T. HORNE AND R. F. MEHL. Carnegie Inst. Technol. Nat'l. Advisory Comm. Aeronaut., Tech. Note No. 3211, April, 1954, 34 pp.

Effect of overstressing on the fatigue properties of SAE 4340 was studied statistically. Effect of microstructure on susceptibility to reduction in fatigue life due to cycles was investigated and the quenched and spheroidized structure proved more susceptible to fatigue damage. Endurance-limit statistics of damaged specimens were determined by the probit method. The decrease in the mean endurance limit due to cycles of overstressing was much greater than expected from non-statistical investigations. The effect is evidence that bulk of fatigue damage occurs before the first 30% of total fatigue life. The appendix comprises supplementary methods measuring fatigue damage and presents overstressing tests on steel and on

aluminum alloys. Tables, graphs, photomicrographs, 29 references.—INCO. 7629

3.5.8, 6.3.6, 6.4.4

Intergranular Cavitation in Stressed Metals. J. N. GREENWOOD, D. R. MILLER AND J. W. SUITER. *Acta Metallurgica*, 2, No. 2, 250-258 (1954) March.

It was found that when copper, α -brass and magnesium are strained at elevated temperatures, cavities appear in the intercrystalline boundaries. The cavities appear to nucleate at regular intervals and under the tensile stress ultimately link to form intercrystalline cracks. This intergranular cavitation is accompanied by a loss of ductility. Graphs, tables, photomicrographs and 15 references.—INCO. 7621

3.7 Metallurgical Effects

3.7.3, 3.5.8, 5.9.3

Effect of Shot-Peening Variables and Residual Stresses on Fatigue Life. R. L. MATTHEWSON AND W. S. COLEMAN, JR. Gen. Motors Corp. Paper before SAE, Hershey, Pa., October, 1953. *Metal Progress*, 65, No. 5, 108-112 (1954) May; *Trans. Soc. Automotive Engrs.*, 62, 546-556 (1954).

Program of testing and analysis was initiated by Research Labs. Div. of Gen. Motors Corp. to shed some light on the relationship of variables in the shot-peening process to fatigue life and on the function of the resulting residual stresses. Specimens of SAE 5147 and 5150 in the form of leaf springs were given various shot-peening treatments and then fatigue tested. A summary of these results with 3 types of shot is given. As a basis for comparison, non-peened springs have a fatigue life of 4500-5900 cycles. Data from stress analysis of specimens are summarized. Graphs.—INCO. 7592

3.7.3, 6.2.3, 3.5.8

A Further Investigation of the Effect of Surface Finish on Fatigue Properties at Elevated Temperatures. R. L. FERGUSON. Lewis Flight Propulsion Lab. Nat'l. Advisory Comm. Aeronaut., Tech. Note No. 3142, 27 pp., March, 1954.

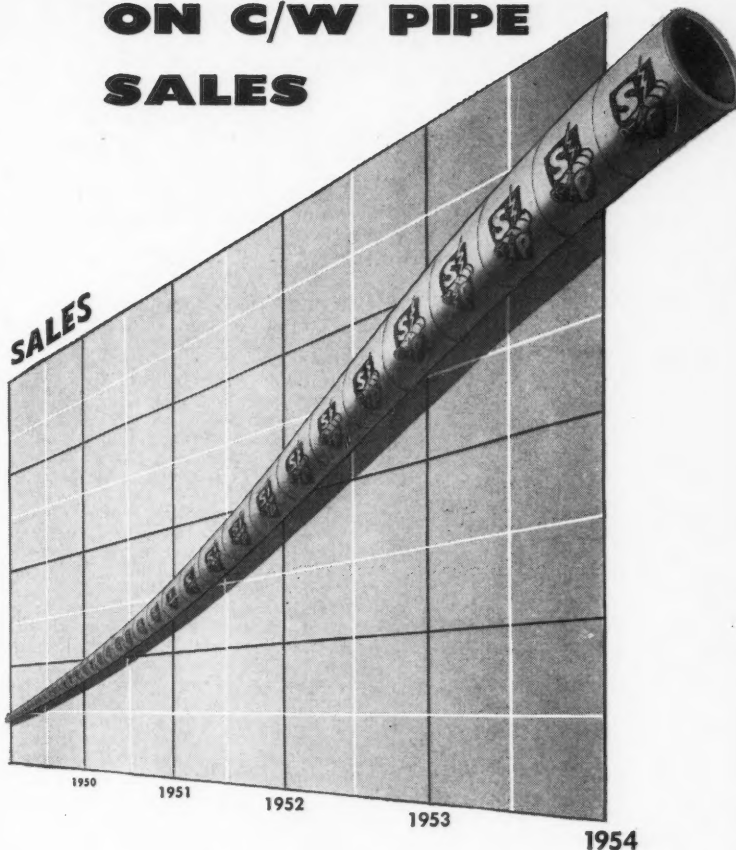
Investigation was conducted to evaluate the effects of surface roughness on fatigue properties of low-carbon N-155 alloy with a grain size of ASTM 6 and of S-816 alloy with a grain size of ASTM 6-7. Fatigue studies were conducted at 80°, 1200°, 1350°, and 1500° F. Investigation of the effect of surface abrasion upon the nature, direction, magnitude, and depth of residual stresses and of the effect of time and temperature upon the relief of these stresses was also conducted. Photomicrographs, tables, graphs and 10 references.—INCO. 7680

3.7.3, 6.2.5

Maintaining the Corrosion Resistance of Welded Stainless Steel. J. P. MOORE. *Corrosion Technology*, 1, No. 4, 92-96 (1954) June.

After-weld corrosion of stainless steels is associated mainly with metallurgical changes in the material brought about by the process of welding. This is illustrated in the case of the austenitic steels by intergranular disintegration or "weld decay" and the "knife line" attack. The process of welding brings about phase formation, and a lowering of the corrosion resistance locally within the mate-

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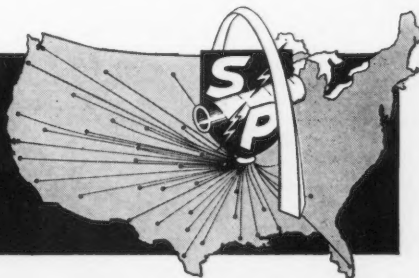


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rial. The process itself with its high heat input associated with the unusual properties of the steel, results in the formation of high local stresses which, if not relieved, may lead to stress corrosion in service. 5 references.—INCO. 7649

3.7.4, 6.4.1, 6.3.1

Practical Effects of the Grain on the Texture of Non-Ferrous Metals. (In French). JEAN HERENGUEL. *Metaux Corrosion Industries*, 29, No. 341, 1-13 (1954) January.

Recrystallization properties are largely influenced by the original solidification texture. At the moment of solidification the crystalline structure depends on several factors such as the number of solidification nuclei, the degree of metallic superfusion, the temperature gradient as a result of the degree of heat flow. Different solidification textures are observed: (1) basaltic texture, which is found in aluminum and alloys of high purity. The orientation of the grain axis is (100); (2) crossed twins, encountered specially in semi-continuous castings of aluminum and aluminum alloys, oriented (111), (112); (3) equiaxial texture. Practical effects of the texture on the properties have been studied in castings, weldments, and test pieces for corrosion tests. Grain size and orientation texture are responsible for the mechanical properties. Grain size and heterogeneity of texture have furthermore an influence on the formation of fissures and inter-granular cohesion which is very important in rolling. For copper-aluminum alloys hot rolling is not possible without fissure if the grain size exceeds 3 to 4 mm. ($Al \geq 6\%$). In forgings and extrusions coarse grain structure is less disadvantageous. Homogenization qualities also depend on the texture. Heterogeneous texture continues through recrystallization. Certain textures, such as crossed twins, result in highly oriented annealing textures after recrystallization. Therefore different ways to modify the solution textures are found, such as rapid cooling, elimination of overheating, additions of titanium, zirconium, to aluminum alloys, etc. It is shown how the grain size depends on the conditions of the cold-hardening-annealing cycle. The heating velocity has a very important influence on aluminum and alloys. The practical effects of the original orientation and the working process on the mechanical properties and plastic deformation are discussed. Grain size has a very marked influence on mechanical qualities and plastic deformation of aluminum and magnesium alloys. To achieve good workability the grain size should be fine and no texture of preferred general or local orientation should prevail. The influence of the texture on physical and chemical properties of metals are studied. Grain size has no considerable influence on the chemical properties. Preferred orientation has an influence on the chemical resistance of the metal. Heterogeneity also has an influence on the chemical properties.—ALL. 7698

3.8 Miscellaneous Principles

3.8.2, 2.1.1.

Thermodynamics of Irreversible Processes Applied to Corrosion. P. A. JOHNSON AND A. L. BABB. *Univ. Wash. Ind. & Eng. Chem.*, 46, No. 3, 518-522 (1954) March.

Study was made to compare the cor-

rosion rates of commercial steel in dilute potassium chloride solution as determined by both gravimetric methods and calculation of the corrosion rate from the equation given. The concepts of the thermodynamics of irreversible processes were applied to the electrochemical reactions occurring on the surface of a metal corroding in solution. From these considerations it appears that derivation of the equation requires that there be no coupling between the several electrochemical reactions occurring on the electrode. A more general equation for the corrosion current is proposed for the case in which the coupling effect is not negligible. Equations and graphs.—INCO. 7666

3.8.3, 6.2.5, 6.3.15, 5.8.4

Potentials of Iron, 18-8, and Titanium in Passivating Solutions. H. H. UHLIG AND A. GEARY. Paper before Wrightsville Beach Mtg., Sept. 12-16, 1953. *J. Electrochem. Soc.*, 101, No. 5, 215-224 (1954) May.

Passivity of 18-8 and titanium in sulfuric acid containing cupric or ferric salts appears similarly to be accompanied by adsorption of Cu^{++} or Fe^{+++} . The irreversible nature of the potentials is in accord with the view that the adsorbate, in part, is chemisorbed. Hydroxyl ions in 4% sodium chloride produce more active potentials in passive 18-8 or titanium presumably by displacing adsorbed oxygen. Potentials of 18-8 in alkaline sodium chloride as a function of partial pressure of oxygen follow the adsorption isotherm, which adds confirming evidence that an adsorbed oxygen film is responsible for passivity. The decreased potentials between active and passive areas plus precipitation of passivity-destroying metal chlorides as hydrous oxides at incipient anodes accounts for inhibition of pitting in chloride solutions by alkalis. Calculated Langmuir isotherm constants, taking into account competitive chemisorption processes agree qualitatively with expected relative values based on chemical properties of metals and adsorbates. Data given, 47 references.—INCO. 7673

4. CORROSIVE ENVIRONMENTS

4.3 Chemicals, Inorganic

4.3.6, 6.2.5

Corrosion of 18-8 Steel by Aqueous Solutions of Ammonium Sulfate and Its Prevention. K. SUGIBAYASHI. *Chemical Engineering (Japan)*, 3, No. 1, 16-20 (1954) Jan.

Corrosion of 18-8 stainless steel by aqueous solutions of ammonium sulfate and its protection are studied under various conditions.

Results obtained are:

1. Corrosion of 18-8 increases slowly at temperatures above 90° C. 2. When sulfuric acid concentration is constant, corrosion rate is reduced with increase of ammonium sulfate content and is minimized when it gets saturated. 3. Most of 18-8 modifications are more corroding than ordinary 18-8, except 18-8 molybdenum. 4. 18-12 molybdenum-copper stainless alloy performed best in the plant test. 5. When 18-8 is in contact with lead (or bronze) in the liquor, corrosion of 18-8 (active) is accelerated. When it is in passive state, however, rate of corrosion is lowered, while the corrosion of lead (or bronze)

is greatly accelerated in turn. 6. Corrosion of 18-8 stops when more than 0.26% cupric sulfate is added. 7. Corrosion loss in weight is diminished to about 4.5% by the addition of more than 0.3% sodium orthoarsenate.—JSPS. 7659

4.5 Soil

4.5.3, 1.6, 6.2.1, 2.2.6

Voor de Bestudering van Buisaantasting Door Bodeminvloeden. (In Dutch). 110 pp., April, 1954. Mededeling No. 27, Rapport van Corrosie Commissie II, Corrosie-Instituut T.N.O., Postbus 49, Delft, Holland.

This is a report on tests started in 1938 to determine the aggressiveness of certain soils against cast iron and steel. Four-inch pipe made of centrifugal cast iron, as cast; centrifugal cast iron with the skin turned off; steel, with mill scale and steel pickled in phosphoric acid were buried in six different types of soil. Every two years three specimens of each tube are removed from each site and examined. Pitting, loss of weight, chemical composition of the soil and corrosion products are determined.

Conclusions reached so far indicate the skin of the cast iron pipes is protective in active sulfate reduction soils, giving them longer life than the steel pipes; the skin was not as protective in acid soils, but the corrosion of cast iron was less than that of steel; mill scale is harmful in soils actively reductive but not in sandy soils; calcareous sand or marl backfill reduces corrosion in acid soils but has little effect in sulfate reducing soils.

Corrosion of all samples was severe in active reducing soil, heavy in acid soils and least in sandy soils. In sulfate soils the corrosion products do not form a crust on the surface of the tube; in aerobic soils the crusts are of the sandy type; in acid soils they are red rust on the outside with some iron sulfide near the surface of the tubes.

Extensive tables of analyses of the corrosion products, pitting and soils are included. 7696

4.6 Water and Steam

4.6.2, 5.8.2, 8.5.3, 7.4.2

Film Forming Corrosion Inhibitors Also Aid Heat Transfer. W. A. TANZOLA AND J. G. WEIDMAN. *Paper Ind.*, 36, No. 1, 48-50, 66 (1954) April.

Paper mill's dryer capacity is increased 5-10% by feeding film-forming amines into the steam. The amine prevents corrosion-film formation on the inside of the dryer and causes dropwise condensation of steam. Spherical drops of condensate leave a substantial portion of condensing surface exposed to the steam and available for effecting heat transfer at its maximum rate. The overall rate of heat transfer depends on the thermal conductivity and thickness of the metallic wall, the conductance of the condensate and water films on both sides of the dryer wall, and the conductance of the scale or corrosion film on the steam side. Equations for estimating the increase in heat transfer coefficient are presented. The case histories of 5 mills using Permacol as the filming amine dispersion are cited. Illustrations. Seven references.—INCO. 7682

4.6.2, 7.6.4, 2.3.4

Boiler Water Chemistry. Papers before ACS, Symp. on "Boiler Water Chemistry," Jt. Mtg. of Div. Water, Sewage, & Sanitation Chem. & Jt. Res. Comm. Boiler Feedwater Studies, 124th Mtg., Chicago, September 7-11, 1953. *Ind. & Eng. Chem.*, **46**, No. 5, 953-977 (1954) May.

Papers include: "Practical Performance of Water-Conditioning Gadgets," B. Q. Welder and E. P. Partridge; "Analysis of Water-Formed Deposits," F. U. Neat and A. A. Berk; "Scheme for Analysis of Industrial Water," J. H. Phillips and K. G. Stoffer; "Significance and Application of Water Analysis Data," R. C. Ulmer; "Significance of Boiler Deposit Analysis," F. E. Clarke and R. D. Hopkins; "Internal Cleaning of Boilers," J. M. Maloney; "Preparation of Feed Water Make-Up," S. B. Applebaum; "Deposits in Boilers," C. Jacklin; "Corrosion in the Boiler," R. F. Andres; "Foaming in Boilers," W. L. Denman; "After Boiler Corrosion," J. J. Maguire. Papers discuss analysis of water and water-formed deposits, inhibitors, and the prevention of scale and corrosion in boilers.—INCO 7653

4.6.4, 2.2.3, 6.4.2

Corrosion and Its Control in Aluminum Cooling Towers. SIDNEY SUSSMAN AND J. R. AKERS. *Corrosion*, **10**, No. 5, 151-159 (1954) May.

Data and illustrations are presented from a field study in which test coupons of six commercial aluminum compositions were immersed in circulating waters in operating cooling towers in New York, Philadelphia and Washington where corrosion has been a troublesome operating problem. Serious pitting of the aluminum occurred with untreated and improperly treated circulating waters. With correct and controlled water treatment, no appreciable corrosion of the aluminum took place.

On the basis of this study and observations of aluminum cooling towers in service, recommendations are offered for the design and operation of cooling towers made of aluminum. These include selection of the construction materials with a view toward corrosion resistance as well as physical properties, design to avoid corrosion promoting conditions, painting for protection of particularly sensitive portions of the equipment, good housekeeping and the continuous application of adequate corrosion inhibiting chemicals to the circulating water. 7603

4.7 Molten Metals**4.7, 6.6.6, 2.3.4**

Stability of Refractories in Liquid Metals. E. L. REED. *North American Aviation, Inc. J. Am. Ceram. Soc.*, **37**, 146-153 (1954) March.

Present technological developments are making more extensive use of liquid metals as heat transfer agents. Their stable and relatively noncorrosive character makes them especially adaptable for high-temperature applications. The compatibility of various liquid metals with refractories has been investigated in the past over a temperature range up to several hundred degrees centigrade. To extend this information to much higher temperatures, corrosion experiments were carried out utilizing liquid sodium, tin, and bismuth. Tests were

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conducted in the range 800 to 1500° C using molybdenum, tantalum, tungsten, graphite, alumina, zirconia, and other materials. The experimental apparatus and procedures employed in conducting both static and dynamic tests are described, and significant results are summarized.—NSA. 7595

6. MATERIALS OF CONSTRUCTION

6.3 Non-Ferrous Metals and Alloys—Heavy

6.3.2, 3.2.3, 5.9.4

Cold and Anodic Oxidation of Cadmium. Researches on the Film Structure. G. BIANCHI. *Metallurgia Italiana*, 46, 49-53 (1953) Feb.

Investigation on the nature and on the relationship of orientation with the base metal of the films formed on cadmium monocrystals by oxidation in air or by anodic treatment in sodium hydroxide solutions. Particularly for the cadmium hydroxide it was found that the relationships of orientation with the base metal are very simple and involve the coincidence of the cadmium hydroxide crystallographic axes with the crystallographic axes of the base metal. For the cadmium oxide films the relationships of orientation with the base metal are more complex.—MI. 7477

6.3.6, 3.5.8

A New Look at Deformation in Copper and Alpha Brasses. A. M. HALSTEAD, J. M. MCCAUGHEY AND H. MARKUS. *Product Eng.*, 25, No. 1, 180-185 (1954) Jan.

Compressive tests on OFHC copper, "commercial bronze" (copper-10.6% zinc), low brass (copper-19.83% zinc), and cartridge brass, by a method permitting continuous strain measurement. The data indicate that stress is not an exponential function of strain, and that the initial yielding is similar to that found in steel. Curves showing effects of grain size and zinc content are also given.—BNF. 7261

6.3.6, 3.6.5

The Electrode Behaviour of Copper. A. K. WIEBE AND C. A. WINKLER. *Can J. Chem.*, 31, No. 11, 1118-1126 (1953) Nov.

Potentials ranging from -0.063v to +0.044v were observed for freshly prepared copper electrodes in sulfuric acid. The potential was dependent on the concentration of the electrolyte, the gas with which the electrolyte was saturated, the nature of the electrode surface, and the intensity of the stirring.—BNF. 7186

6.3.6, 3.7.2

Effect of Arsenic on Hot Working and on Welding of Copper. (In German). A. SCHLEICHER. *Acta Tech. Acad. Sci. Hung.*, 6, No. 1-2, 201-207 (1953).

On the basis of tests on copper containing arsenic (and upwards of 1% silver) it is concluded that 0.8% arsenic renders copper hot-short. Oxyacetylene welding tests on copper firebox plates with welding wire containing 0.5% arsenic and 1.84% silver, thought to suggest that arsenic does not affect weldability of copper but tensile strength and elongation are slightly reduced.—BNF. 7205

6.3.6, 3.7.2

The Extrusion of Brass Rod and Section. D. J. BROADLEY. *Australasian Engr.*, 1953, 67-73, July.

Equipment for melting and extruding brass is described. Various additions are made to the basic 60:40 zinc-copper alloy in order to produce alloys with special properties; lead up to 3.5% improves machinability, tin up to 1.5% improves corrosion-resistance. High-tensile brass contains tin, iron, manganese, and aluminum. Applications are discussed.—MA. 7398

6.3.6, 3.7.2, 4.6.1

Corrosion Behaviour of Iron Containing 90/10 Copper-Nickel Alloys. K. KRAFAK AND E. FRANKE. *Werkstoffe u. Korrosion*, 4, 310-315 (1953) Aug./Sept.

Effect of small quantities of iron in improving corrosion-resistance of copper-nickel alloys. Comparative corrosion test results are given for 90/10

base copper-nickel alloys containing 0.7 and 2% iron in contact with pure seawater, rapidly-flowing seawater, steam condensate, exhaust water, chlorine water, etc. Results clearly show the corrosion-resistant enhancing effect of small quantities of iron.—INCO. 7083

6.3.3, 5.3.4, 5.3.2

Chromium. A. H. SULLY. Book, 1954, 272 pp. Butterworths Scientific Publications, London. 35s.

The systematic literature of chromium is thin, and Dr. Sully's present survey is therefore all the more welcome, particularly as he has in recent years been investigating the properties of the metal and its alloys. It covers a wide field: occurrence of the metal; production of ferro-chrome and pure chromium; physical properties; melting and casting, powder metallurgy and workability; electroplating and properties of the deposits; chromising; constitution and properties of chromium alloys.

Chromium, for a variety of reasons, has been less investigated perhaps than it might have been. Dr. Sully's succinct, up-to-date account (which includes some very recent references) should spur metallurgists to further study of this interesting metal.—BNF. 7237

6.3.6


Engineering Coppers. J. L. EVERHART. *Materials & Methods*, 38, No. 6, 123-138 (1953) Dec.

Various types of American commercial coppers: electrolytic; fire-refined; arsenic-, silver-, selenium- and tellurium-bearing copper; oxygen-free; phosphorized; and others. Physical and mechanical properties; high-temperature properties; corrosion resistance; processing characteristics (forming and fabrication, heat treatment, machining, jointing and surface finishing); applications.—BNF. 7480


6.3.6, 3.2.3

Growth of Sulphide Films on Copper. T. P. HOAR AND A. J. P. TUCKER. *J. Inst. Metals*, 81, No. 12, 665-679 (1953).

Investigations into the growth and structure of sulfide films on copper produced under simple conditions in liquid media, are described. The reaction of copper with sulfur dissolved in benzene produces "cuprous sulfide" of composition between $\text{Cu}_{1.66}\text{S}$ and $\text{Cu}_{1.5}\text{S}$. The attack is not uniform; those parts of the sulfide layer that form the most rapidly have the lowest copper content. The rate of attack increases with sulfur concentration. The reaction of copper with dilute aqueous ammonium polysulfide solution for a few minutes produces films showing interference colors, which have been used to estimate the rate of film growth. The rate is initially approximately constant with time ("rectilinear" growth), proportional to the total polysulfide concentration, an increased by increase of the illumination of the tarnishing surface; during the later stages of growth, the rate becomes inversely proportional to film thickness ("parabolic" growth), and much less dependent upon polysulfide concentration and upon intensity of illumination. The rate of increase by increase of pH of the attacking solution. The results are explained by an extension of the electrochemical theory of film thickening by lattice transport; in the early stages of film growth the major rate-determining process is the arrival by diffusion of active polysulfide ions at the



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film surface, while in the later stages the rate-determining process is the migration of cuprous ions through the film. The results are compared with those for iodide films on copper and silver, and a general scheme is suggested. When electrolytically polished copper is tarnished with polysulfide solution, films of different colors are obtained on each grain. On annealed material, the film on any one grain is of uniform color, and is monocrystalline. Although grains of many different orientations are present, only relatively few differently colored films are formed. Many minute polarization figures on each grain are sometimes visible when the specimen is viewed in convergent plane-polarized light, indicating that growth resulting in a monocrystalline film begins from many nuclei. Sulfide films grown on plastically deformed copper are more complicated; heavily worked material shows uneven films, and slightly deformed material gives films showing optical peculiarities at the metal slip bands. The results are compared with similar observations on films of cuprous iodide and oxide on copper and brass and of AgI and Ag₂S on silver.—MA. 7066

6.3.6, 3.2.3, 3.7.2

Kinetics of High-Temperature Oxidation of Selenium Bearing Copper. (In Russian). N. P. DIEV, M. J. KOCHNEV, A. F. PLOTNIKOVA, AND T. N. ZAIDMAN. *J. Applied Chem. (USSR)* (Zhurnal Prikladnoi Khimii), 26, No. 6, 596-604 (1953) June.

It was established that the addition of selenium to copper alloys increases oxidation rate in the temperature range of 600-1000°C. Diagrams, graphs, tables. 12 references.—BTR. 7051

6.3.6, 3.2.3, 3.8.4

High Pressure Oxidation Rate of Metals—Copper in Oxygen. W. McKEWAN (N. J. Zinc Co.) AND W. M. FASSELL, JR. (Univ. Utah). Paper before AIME, Cleveland, Oct. 1953. *J. Metals*, 5, No. 9, Sect. 1, 1127-1130 (1953) Sept. (Trans. AIME, 197).

Oxidation rates of copper were determined at temperatures from 600-900°C. in oxygen from 14.7 to 400 psi total oxygen pressure. Oxidation rate of copper is unchanged by oxygen pressures within the range studied. Observed data extend Feitknecht's conclusion concerning the pressure independence of copper from atmospheric pressure to 400 psi. All samples studied in the above-mentioned temperature and pressure range have both cuprous oxide and cupric oxide present in the oxide film. Graphs, tables and 13 references.—INCO. 7195

6.3.6, 3.2.3, 3.8.4

The Kinetics of the Initial Corrosion of Copper in Aqueous Solutions. G. R. HILL. Univ. Utah. Paper before Electrochem. Soc., Buffalo Mtg., Oct. 11-14, 1950. *J. Electrochem. Soc.*, 100, No. 8, 345-350 (1953) Aug.

To determine the mechanism and rate of corrosion of copper in aqueous solution before diffusion through a film of products becomes rate-determining, an electro-reduction cell coupled to a recording electronic voltmeter was constructed for determining the thickness of very thin films of corrosion products on the copper surface. These data are used to determine the rate laws regulating the corrosion of the metal and to evaluate the specific rate constant for the initial corrosion process.

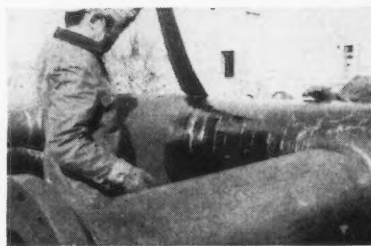
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A mechanism and rate law are proposed for the initial corrosion process. IN potassium chloride was the solution used. Acetate ion changes the process by adsorption, no film of copper oxide being formed in the acetate solution. Graphs, tables, 20 references.—INCO. 7339

6.3.6, 3.4.8, 3.2.2

"Whiskers" Growths on Copper. J. G. M. TURNBULL. *Bull. Inst. Metals*, 2, No. 3, 19 (1953) Nov.

"Whiskers" or "spikes" were found to grow from cathode surfaces in copper electroforming baths when the mains water contained excess chlorine, or in the presence of chloride ions.—BNF. 7371

6.4 Non-Ferrous Metals and Alloys—Light

6.4.2, 3.7.2

The Effect of Iron, Manganese, and Chromium on the Properties in Sheet Form of Aluminium Alloys Containing 0.7% Magnesium and 1.0% Silicon. R. CHADWICK, N. B. MUIR, and H. B. GRAINGER. *J. Inst. Metals* (London), 82, Pt. 2, 75-80 (1953) October.

As part of a systematic investigation of alloys hardened by Mg₂Si precipitation, the effects of 0-0.4% iron and 0-0.6% manganese or chromium have been assessed in materials of constant magnesium and silicon content. The alloys were hot and cold rolled to sheet; after solution heat-treatment and room-temperature aging the properties varied only slightly with composition, strengthening being brought about by all three alloying additions. After subsequent artificial aging at 160°C., alloys free from manganese or chromium were brittle and exhibited intercrystalline fracture in tension. Alloys containing manganese or chromium were both stronger and more ductile, fractures being mainly transcrystalline. Corrosion-resistance was high in the room-temperature-aged materials, but susceptibility to intercrystalline attack was induced by artificial aging. Micrographic studies were particularly concerned with precipitation occurring at different stages in processing and heat-treatment. By analogy with existing equilibrium data in related systems, the probable identities of the precipitate phases, and their significance in relation to the properties of the alloys, are discussed.—MA. 7421

6.4.2, 3.7.2

The Effects of Grain Refining Additions and Alloying With Magnesium Upon Corrosion Resistance of High-Purity Aluminium. (In Hungarian) MARIA H. GYENES. *Aluminium* (Budapest), 5, No. 11, 225-235 (1953) Nov.

Results of investigations with various highly corrosive media are described and compared with data from literature. Tables, graphs, photographs. 24 references.—BTR. 7017

6.4.2, 3.7.3

Soldering of Aluminium. J. D. DOWD. *Welding J.*, Supplement, 33, No. 3, 113s-120s (1954) March.

Aluminum and its alloys can be readily soldered once the oxide film on the surface has been removed. This oxide can be removed mechanically by ultrasonic vibration, abrading with steel wool, wire-brushing or by some similar means while the surface is covered with

molten solder, or it can be removed with fluxes. In general, the resistance to corrosion of soldered joints in aluminum has been found to increase as the zinc content of the solder increases. The best solders from a corrosion viewpoint are zinc-base alloys in which zinc is the lowest melting metal. The resistance to corrosion of soldered joints has also been found to depend upon joint design, environment and effectiveness of protection. Sound soldered joints that are adequately protected have been found to give satisfactory service in various environments for many years.—ALL. 7469

6.4.2, 3.7.3, 4.3.2

The Corrosion Effects of Varying Concentrations of Nitric and Sulphuric Acids Upon Welds on Aluminium and Its Alloys. WALDEMAR BLEICHER and ALBRECHT MÜLLER-BUSSE. *Werkstoff u. Korrosion*, 4, No. 8/9, 273-280 (1953) August/September.

The action of sulfuric and nitric acids upon welded joints on aluminum and various aluminum alloys was examined. Low concentrations of sulfuric acid act first of all on the welded seam of all aluminum materials in use in industry. With higher concentrations, the effect is evenly distributed over the whole surface. Welded aluminum was shown to be highly resistant against concentrations of nitric acid varying between 1 and 65%. In the case of welded aluminum alloys, the welded seam was also the first to be acted on by medium concentrations of sulfuric acid. Welded joints made by the autogenous or the metal-arc processes do not show any great variation in their resistance to corrosion. Annealing or hammering the welds, as well as hammering followed by annealing, has, when made under the conditions obtained during this examination, no effect upon the resistance to corrosion.—ALL. 7385

6.4.2, 4.3.2, 3.8.3

The Phenomena of Passivation of Aluminum Immersed in a Nitric Medium. (In French). JOSEPH PATRIE. *Rev. Aluminium*, 29, No. 194, 431-437 (1952) Dec.; *ibid.*: 30, Nos. 195 & 196; 5-11, 45-54 (1953) Jan., Feb.

Part I shows that passivation of aluminum immersed in acidic oxidizing solutions frequently involves complex reactions which are difficult to identify. A theoretical Al/H₂O diagram taking into account pH and potential coordinates is presented. Part II describes use of non-insulated aluminum and interprets results concerning galvanic oxidation process in concentrated nitric acid. Part III deals with galvanic oxidation of aluminum in nitric acid and chromic acid. Oxidation time, current density, temperature, and nature of the electrolyte are included.—BTR. 6994

6.4.2, 4.2.4, 2.2.2

Resistance of Aluminium and Its Alloys to Corrosion in Industrial Atmospheres. (In Italian). G. LUFT and A. PERONE. *Alluminio*, 22, No. 3, 256-269 (1953).

Specimens of aluminum, several standard aluminum alloys clad and unclad and with and without organic surface coatings, together with specimens of iron, with and without surface protection, were exposed to an industrial atmosphere containing nitrous oxide, nitric oxide, sulfur dioxide, carbon dioxide, sulfur trioxide, calcium nitrate dust, etc., and to

a borax-containing atmosphere at another factory. Specimens were removed for examination (external appearance, tensile tests, some microscopic examination of sections) after 3, 6 and 12 months in the first case and after 3, 6, 16, and 24 months' exposure in the second. Corrosion was found to have been much more severe in the former. It is, however, concluded that adequate resistance to corrosion can be obtained by a suitable choice of alloy and surface treatment.—RPI. 7078

6.4.2, 4.4.5, 3.7.2

Mechanism of Reaction of Aluminium and Aluminium Alloys with Carbon Tetrachloride. M. STERN and H. H. UHLIG. *J. Electrochem. Soc.*, 100, No. 12, 543-552 (1953) Dec.

Effects of alloying elements on induction period and corrosion rate. The induction time could be reduced by first heating the metal in vacuo at 400°C., presumably owing to damage to the oxide film. No change was observed with aluminum-magnesium alloys, however. The mechanism for the reaction is attributed to a sequence of free radicals. 17 references. 7203

6.4.2, 3.2.3, 5.9.4

Oxide Growth on Different Crystal Faces of Aluminium. S. J. BASINSKA, I. J. POLLING and A. CHARLESBY. *Acta Metallurgica*, 2, No. 2, 313-317 (1954) Mar.

Growth of oxide on different crystal faces of aluminum was studied. Oxide films were formed electrolytically, so that the potential difference across the oxide was known. Thickness of the oxide was obtained by a study of the interference colors shown by these thin films. No significant variation in oxide thickness was observed on different crystal faces. Table, figures and three references.—INCO. 7457

6.4.2, 3.5.8, 1.3

Stress-Corrosion in Aluminium Alloys. (In German). P. BRENNER. *Z. Metallkunde*, 44, No. 3, 85-97 (1953) March.

A survey of knowledge. Terminology; testing, aluminum-magnesium-copper, aluminum-copper, aluminum-copper-magnesium, aluminum-zinc-magnesium-copper; clad alloys. Causes of stress-corrosion in aluminum alloys; and prevention in super-saturated alloys. Lists four measures for elimination of corrosion sensitivity of aluminum alloys. Photographs, graphs, diagrams. 59 references. 7058

6.4.2, 3.5.8, 2.1.2, 2.3.7

Stress-Corrosion of Aluminium-Magnesium Alloys. Part I. The Effect of Tensile Stress on the Corrosion of Aluminium-7% Magnesium and Aluminium-5% Magnesium Alloys. Part II. Methods for Expressing Stress-Corrosion Susceptibility on a Comparative Basis. E. L. JONES. *J. Applied Chem.* (London), 4, Pt. 1, 1-10 (1954) Jan.

Effect of tensile stress on the corrosion of commercial purity aluminum-magnesium alloys was determined by subjecting the alloys to intermittent immersion in 3% sodium chloride solution. Overstraining 10%, followed by aging at 125° for 24 hours, renders aluminum-7% magnesium susceptible to stress-corrosion with applied stresses as low as 2% of the U.T.S. (ultimate tensile strength), and aluminum-5% magnesium alloy with stresses greater than 24% of the U.T.S. Stresses smaller than the threshold

stress have little effect on the rate of attack. Under comparable stresses, the time-to-failure of the 5% magnesium alloy is greater than that of the 7% magnesium alloy. Presentation of data obtained from the stress-corrosion experiments is discussed, and methods are suggested by which the susceptibility to stress-corrosion of materials may be expressed on a comparative basis. Results given in Pt. I are used to illustrate the methods. Tables, graphs, 9 references.—INCO. 7257

6.4.2, 3.5.8, 3.7.4

Some Metallographic Observations of the Creep of Aluminum-Copper Alloys. A. H. SULLY AND H. K. HARDY. *J. Inst. Metals*, 82, Pt. 6, 264-265 (1954) Feb.

In aluminum-copper alloys containing 3 and 4% copper, creep at 190°C. occurred preferentially in relatively narrow regions, depleted in solute, on either side of the grain boundary. Plastic flow accentuated the precipitation process in the material immediately adjacent to the grain boundary, thus widening the band of material with a low resistance to deformation. Shear displacement across boundaries favorably oriented to the applied stress was accompanied by the formation of fissures transverse to the stress direction. High-purity alloys showed the effects most prominently and gave intercrystalline fractures. Normal-purity alloys possessed a much better creep resistance, but also gave intercrystalline failure when previously aged at 190°C. Normal-purity material aged at 300°C. gave ductile fractures associated with longitudinal fissures in the necked region. Results point to the importance of grain-boundary stability in creep-resistant alloys. Tables.—INCO. 7305

6.6 Non-Metallic Materials

6.6.5

Chemical Resistant Cement Reference Sheet. RAYMOND B. SEYMOUR AND ROBERT H. STEINER. *Chem. Eng. Progress* (Engineering Section), 49, 220 (1953) April.

Discusses applications, composition, workability, and corrosion resistance of epoxy cement. Tables.—BTR. 7352

6.6.8, 7.2, 8.4.2

What Has the Gas Industry Experienced to Date With Plastic Pipe? JOHN F. FUGAZZI. *Gas Age*, 111, 54, 81-82 (1953) May 7.

Some 25,000 services indicate no failure with natural gas that can be attributed to failure of material. Presents details of material, sizes, and assembly.—BTR. 7039

6.6.8, 8.8.1

Proper Fabrication of Unplasticized PVC Equipment. G. S. LAFF. The Bolta Co. Paper before ASME, Spring Mtg., Columbus, Apr. 28, 1953. *Chem. Eng.*, 60, No. 6, 312-318 (1953) June.

Selection of a plastic for use in chemical process equipment involves a careful balance of economic considerations with physical properties, corrosion resistance, and fabricating possibilities. Unplasticized vs. rigid PVC, tests for unplasticized PVC, welding, machining and molding are covered. Diagrams.—INCO. 7071

6.6.10, 6.6.8, 2.3.4

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of Impurities in the Acetate Textile Industry. R. H. MCKINLAY. *Fibres* (London), 15, No. 2, 39-42 (1954) Feb.

Methods of analysis employed for the detection and determination of traces of metals in raw materials, intermediate and finished products in the acetate textile industry. Analysis is based on colorimetric methods. Procedures for the detection of iron, copper, manganese, lead, zinc, nickel, chromium, calcium, aluminum, chlorine, silica, and sulfur, are described.—INCO. 7306

6.6.8, 2.2.3, 8.8.1

Use of Plastics as Materials of Construction in the Chemical Industry. S. W. SHEPARD. *Corrosion*, 10, No. 7, 215-216 (1954) July.

A number of case histories are given in which experimental or emergency use of plastics as materials of construction has subsequently led to their formal adoption. Principal materials referred to are the various polyester laminates, polyvinylidene chloride and fluorocarbons. The author cites the need for a reliable nondestructive test for the physical properties of reinforced plastics. Accounts are given of successful use of plastics in gas and liquid phase operations involving various corrosives. 7570

6.6.11, 4.6.11

Behavior of Wood G. M. HUNT. *Research* (London), 6, No. 8, 295-301 (1953) August.

Describes destruction of wood in salt water by marine borers, such as Teredo and Bankia. Best protection against shipworm attack is to impregnate the wood with coal-tar creosote.—INCO. 7002

7. EQUIPMENT

7.1 Engines, Bearings and Turbines

7.1

Sleeve Bearing Application Factors. R. H. JOSEPHSON. Cleveland Graphite Bronze Co. *Elec. Mfg.*, 53, No. 4, 142-148, 372, 374 (1954) April.

Sleeve bearings are now capable of carrying heavier loads at higher speeds and temperatures for longer periods of time than they ever have before. Requirements for bearing materials are resistance to fatigue, good surface action, conformability, embeddability, and corrosion resistance (high and low temperature and sulfur corrosion). Bearing materials briefly discussed include babbit alloys (tin- and lead-base alloys), copper-lead alloys and tri-metal bearings. Lubrication and application problems, grooving and clearance design, endurance and life and load calculations are considered. Tables, bibliography.—INCO. 7551

7.1

High Performance Jet Engine Design Dependent Upon Metallurgical Ingenuity. I. PERLMUTTER. *Wright Air Dev. Center. J. Metals, Sect. I*, 6, No. 2 113-118 (1954) Feb.

Materials for high performance engines are discussed. Compressor conditions and materials including an iron base austenitic precipitation hardening alloy, A-286 (containing 26.0% nickel) are described. 16-25-6 alloy has been

INDEX TO ADVERTISERS

VOL. 11 JANUARY, 1955 NO. 1

Allen Cathodic Protection Co.	101
Amercoat Corporation	Inside Front Cover
American Chemical Paint Company	107
American Hot Dip Galvanizers Association, Inc.	112
Apex Smelting Company	108
Branch-Kracy Co., Inc.	8
Carboline Company	111
Cathodic Protection Service	15
Coast Paint & Lacquer Co.	99
Columbia Southern Chemical Corp.	1
Corrosion Directory	76
Corrosion Engineering Directory	75
Corrosion Rectifying Company	96
Corrosion Services Incorporated	91
Dow Chemical Company	2
Duriron Company, Inc.	Inside Back Cover
Hill, Hubbell & Company, Div. of General Paint Corporation	11
Humble Oil & Refining Company	97
International Nickel Company, Inc.	9
International Paint Company, Inc.	74
Johns-Manville Sales Corp.	12
Koppers Company	94
Mayes Brothers, Inc.	81
National Association of Corrosion Engineers	79, 80
National Carbon Division, Union Carbide and Carbon Corp.	72
Pipe Line Anode Corporation	89
Pipeline Coating & Engineering Co., Inc.	87
Pittsburgh Coke & Chemical Co.	Back Cover
Polyken Products, Dept. of the Kendall Company	82
Positions Wanted and Available	86
Prufcoat Laboratories, Inc.	93
St. Joseph Lead Company	14
Standard Magnesium Corporation	6
Standard Pipeprotection, Inc.	105
Tapecoat Company, The	109
Tnemec Company, Inc.	78
Tretolite Company	85
Tube-Kote, Inc.	92
United Chromium, Inc.	7
United States Stoneware Company	13
Visco Products Company, Inc.	77
Williamson, T. D., Inc.	10

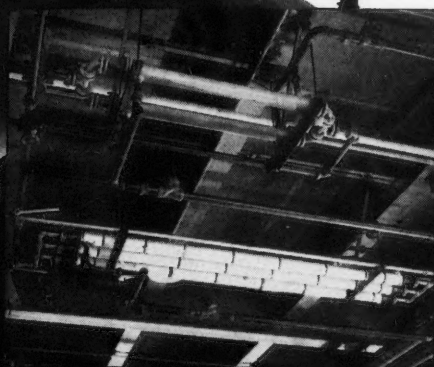
used in turbo-supercharger and jet engine wheels for 11 years. Chronological list of materials used in aircraft turbines and temperature for rupture in 100 hours at 200,000 psi are given. Nominal composition of turbine bucket materials, including KE965 (14.0% nickel), 17W (19.0% nickel), Stellite No. 21 (2.0% nickel), S-816 (20.0% nickel, and Stellite No. 31 (10.0% nickel) are listed. Tables, graphs, and 4 references.—INCO. 7301

7.1

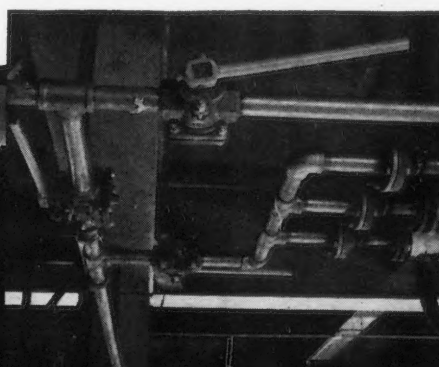
Automotive Engine Bearings. *Lubrication*, 39, 61-76 (1953) May.

Discusses properties required of a bearing material; use of white metal alloys, tin- and lead-base babbitts, cadmium alloys, copper-lead alloys, impregnated copper-nickel alloy, and aluminum alloys; bearing manufacture; lubrication and lubricants; and bearing life, failure, and corrosion. Micrographs, tables, photographs.—BTR. 7081

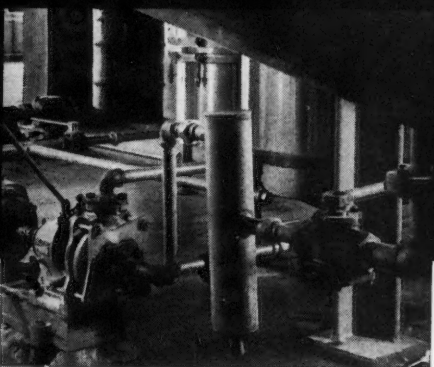
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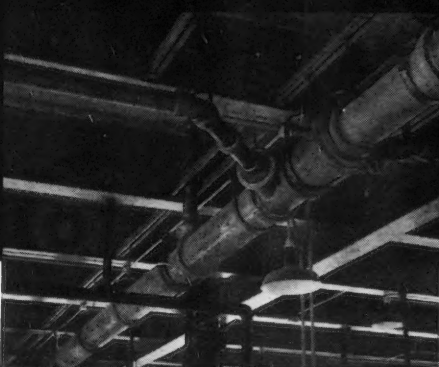
Durco #3C Heat Exchangers (bottom of photo) handling nitrate solutions. (Bulletin M/2) • Durco #4C Heat Exchangers (top) handling sulfuric acid. (Bulletin M/1)



Durco Type F Valves with Teflon sleeves handling nitrate solutions. (Bulletin V/4)



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